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Properties and Uses of Pennsylvania Shales and Clays, Southeastern Pennsylvania

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DEPARTMENT OF ENVIRONMENTAL RESOURCES
BUREAU OF
TOPOGRAPHIC AND GEOLOGIC SURVEY
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PREFACE

Mineral Resources Report M63 contains test results and evaluations of argillaceous rock samples and unconsolidated material from 159 localities in southeastern Pennsylvania. The samples were evaluated for both ceramic and non-ceramic uses. Evaluation indicates 108 potential areas from which material may be obtained for ceramic-ware products or lightweight aggregate. There are also potential sources of filler material in three areas and potential sources of impervious fill in many other areas.

This is the second report of a programmed study relating potential uses to physical, chemical, and geologic properties of shale and clay raw materials. Tables, graphs, and maps are used to correlate, summarize, and evaluate field and laboratory data to make the report valuable to potential users. Several geologic formations of particularly good economic potential have been found and merit further exploration. This report should stimulate further studies of the argillaceous resources of the region and provide basic information needed for industry in the location of additional extractive operations and processing facilities in southeastern Pennsylvania.

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by

Karl V. Hoover, Timothy E. Saylor, Davis M. Lapham, and Miles E. Tyrell

ABSTRACT

Physical, chemical, ceramic and X-ray mineralogical determinative tests were performed on 159 samples from 19 geologic units in 15 southeastern Pennsylvania counties. Evaluation studies suggest 108 samples have a potential for one or more of the following uses: face brick, decorative brick, structural tile, floor tile (quarry tile), flue liner, refractories, lightweight aggregate, stoneware (includes pottery), and filler. Rotary kiln tests were performed on 52 bulk samples for which preliminary quick-firing tests indicated the raw material has a potential for lightweight aggregate use.

The following variables were investigated and are reported for each sample: (1) unfired properties including drying shrinkage, dry strength, water of plasticity, workability, and pH; (2) fired properties such as color, hardness, total shrinkage, absorption, approximate specific gravity (bulk density), P.C.E., firing range, and bloating characteristics; (3) quantitative X-ray mineralogy for quartz mica, kaolinite, feldspar, and chlorite-vermiculite-montmorillonite; (4) quantitative wet chemical analysis for normal silicate rock components; and (5) semiquantitative spectrographic analysis for trace elements (for some samples). Geologic and geographic data are compiled for each sample.

Quantitative comparisons from measurements on raw samples are made between selected variables and their potential use and rock type. Rock type, mineralogy, chemistry, and unfired properties, in decreasing order of significance, have been found to be the more important variables in predicting the use potential of raw materials. Some sample data trends indicate that quantitative determinations of quartz, mica, kaolinite, total iron, and Fe_3/Fe_2 ratio, and possibly pH are useful in prefiring sample evaluation for a potential ceramic use, and particularly for potential use as brick and lightweight aggregate.

INTRODUCTION

This publication is the latest in a series of geologic reports concerning shale and clay resources of Pennsylvania which started in 1898 with the publication of a treatment of the clays of western Pennsylvania by T. C. Hopkins (1898). The most recent investigations of Pennsylvania's shale and clay resources, of which this report is the second (O'Neill and others, 1965), was initiated in 1962 when the Pennsylvania Geological Survey began a cooperative program with the U. S. Bureau of Mines to evaluate clays and shales for commercial use.

In this program the Pennsylvania Geological Survey was responsible for planning and carrying out all field work, sample collection, mineralogical and chemical analyses on the samples, and the correlation of data. The U. S. Bureau of Mines Metallurgy Research Laboratories performed unfired and fired physical properties tests and evaluated their test results in terms of quality potential for economic uses.

The purpose of this report is to suggest potential areas of ceramic quality deposits in the various argillaceous units of southeastern Pennsylvania and to evaluate criteria for their exploitation. For this report, 159 samples were collected from 19 different geologic units in 15 counties of southeastern Pennsylvania. Field information is pre-1967.

It must be realized that a commercial endeavor cannot be undertaken solely on the basis of these test results. Additional sampling and testing is needed to evaluate the extent of a deposit for a particular use or quality. In addition, source material blending and variation in production techniques may affect the use evaluation of a specific deposit. Finally the utility of a raw material is partially based upon the judgements of the analyst and the user so that the evaluations given here may not reflect the true utility of argillaceous raw material for a special use in a particular market locale. At best, the evalutions included here indicate the economic possibilities for the units at the locations sampled. In conjunction with the previous report (O'Neill and others, 1965), a good estimate of variability within a particular geologic unit can be obtained. Certain chemical, mineralogical, and unfired physical properties tests are given which will aid in evaluating materials prior to performing firing tests.

ACKNOWLEDGMENTS

The initial phases of this study were under the supervision of B. J. O'Neill, Jr. He has been responsible for collecting most of the gross (10 pound) samples submitted for potential use evaluation, chemical analy-

sis and X-ray studies as well as many of the bulk (200 pound) samples used in rotary kiln testing for lightweight aggregate.

The project has benefitted from the encouragement and direction of Arthur A. Socolow, Pennsylvania State Geologist. Acknowledgment is also made to many of the Pennsylvania Geological Survey staff who, because of their detailed knowledge of local areas, were helpful in suggesting suitable sampling sites.

Appreciation is extended to U. S. Bureau of Mines personnel, especially R. D. Thomson and Curtis D. Edgerton, coordinating officials for the U. S. Bureau of Mines, and to M. V. Denny, Norris Metallurgy Research Laboratory, who provided technical interpretations and supervised ceramic evalution of the raw samples tested by the Norris, Tennessee, Laboratories.

The authors are appreciative of all company officials and property owners who granted permission and provided assistance in sampling on their properties.

GEOLOGY AND DISTRIBUTION OF ARGILLACEOUS ROCKS IN SOUTHEASTERN PENNSYLVANIA

REGIONAL GEOLOGY

The area designated as southeastern Pennsylvania includes that portion of Pennsylvania lying generally south and east of Blue Mountain (also referred to as Kittatinny, First, or North Mountain). This area encompasses approximately 8,000 square miles and all or parts of 15 counties. A few samples were collected in Schuylkill and Monroe Counties, both of which lie north of the southeastern Pennsylvania sector in the Appalachian Mountain section of the Valley and Ridge province.

The southeastern Pennsylvania area consists of parts of five physiographic provinces (Figure 1). These provinces, from east to west, are the Atlantic Coastal Plain province, the Piedmont province, the Blue Ridge province (South Mountain), the New England province (Reading Prong), and the Great Valley section of the Valley and Ridge province.

The Coastal Plain province is a narrow strip of Cretaceous rock and younger unconsolidated sediments along the Delaware River south from Morrisville, Pa. The Piedmont province immediately west of the Coastal Plain province is underlain chiefly by Precambrian(?) crystalline rocks but locally by Cambro-Ordovician carbonate rock; Triassic conglomerate, sandstone, shale, and diabase occupy the northern and western portion of the province. The Blue Ridge province is composed of Precambrian volcanics which are overlain by quartzites and subordinate

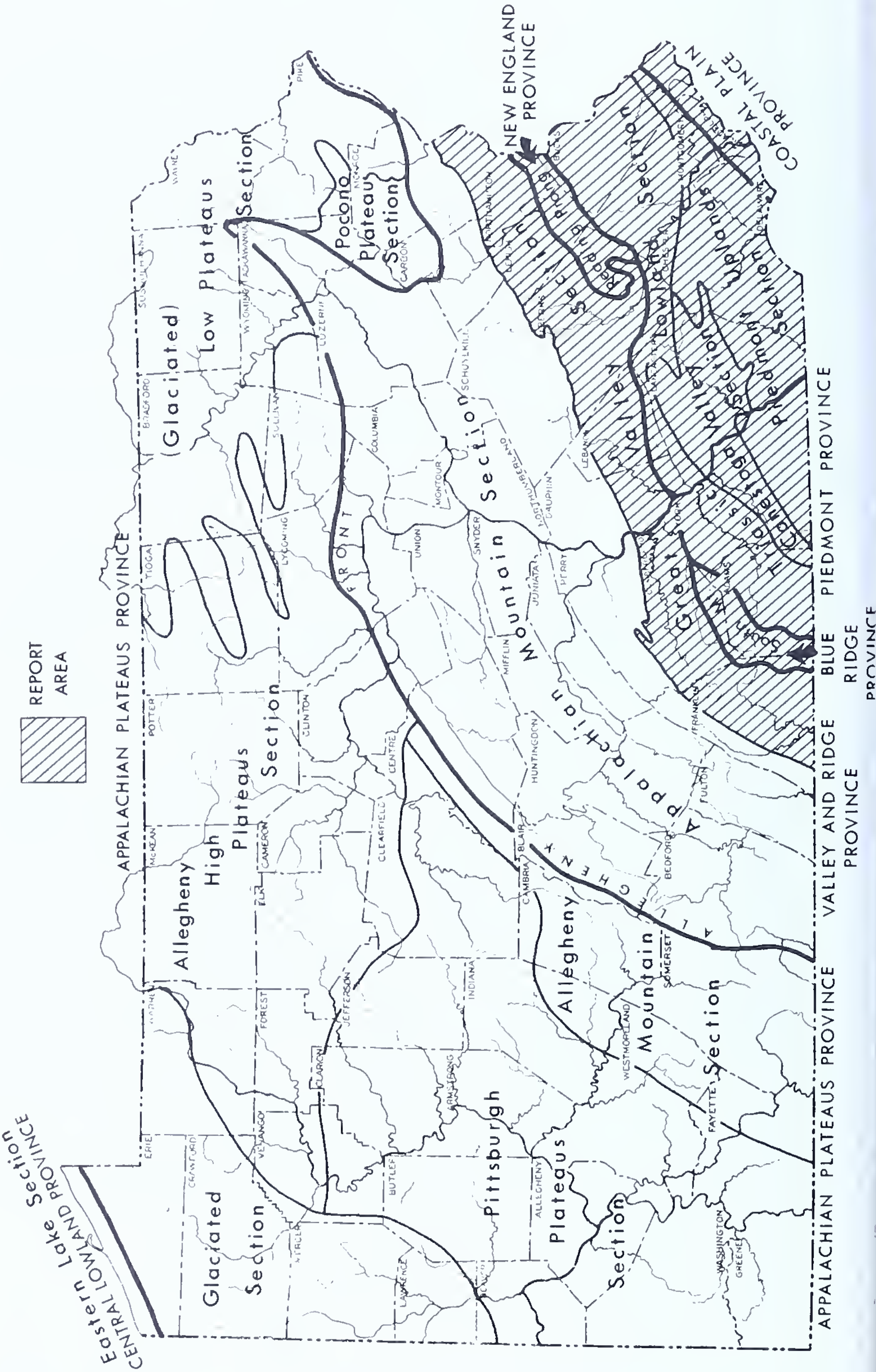


Figure 1. Physiographic provinces of southeastern Pennsylvania showing location of report area.

phyllites. The Reading Prong section of the New England province is composed of Precambrian granite gneiss overlain by a thin quartzite. The Great Valley section of the Valley and Ridge province is underlain by Cambrian and Ordovician carbonate rocks and Ordovician shales.

For the most part, the argillaceous units of southeastern Pennsylvania are pelitic shales and residual clays with local areas of limy shales, siltstone, and slate. The residual clays are either fluvial deposits or weathered carbonates, schists, and, less commonly, shales. Clays, found in topographic lows are generally limited in areal extent and are very thin or mixed with sand and boulders. As a result, they are not considered to be of economic value and have not been sampled for laboratory testing. Argillaceous sediments that have been metamorphosed to phyllites, schists, and slates generally have been found to yield unsuitable fired products and have not been extensively sampled. Rock units singled out for sampling were selected on the basis of areal extent, reasonable unit thickness, and a history of commercial use or suggested potential use.

LITHOLOGIES SAMPLED

The argillaceous materials sampled during this study range from rocks of Precambrian through Triassic age. A brief description and the distribution of each rock unit sampled are given in the legend accompanying Figure 2. A lithologic description of the individual samples is given in the Sample Data and Test Results section of this report.

The Precambrian sericite schist samples collected from the South Mountain area of Adams County are metamorphosed rhyolites. Weathering may be extensive, especially where schistosity is well developed. The sericite schist deposits are generally bounded by metarhyolite or metabasalt.

A white to very light gray clay, apparently a weathering product of an underlying pyrophyllite body, was collected from a quarry near Gargol in Adams County. Light greenish gray pyrophyllite crops out at various locations in the quarry and occurs as en echelon lenses with interbanded greenstone. Diamond core drilling indicates that the pyrophyllite occurs in a series of pod-like lenses each extending 100 to 200 feet along strike with a maximum thickness of less than 25 feet. Exploratory drilling also suggests that the lenses pinch out down dip (60°E). The quarry is presently operated by the Summit Mining Corporation and the clay used as a filler material.

A grab sample of varicolored metarhyolite schist, collected in Cumberland County from an excavation dump, upon testing proved to have no

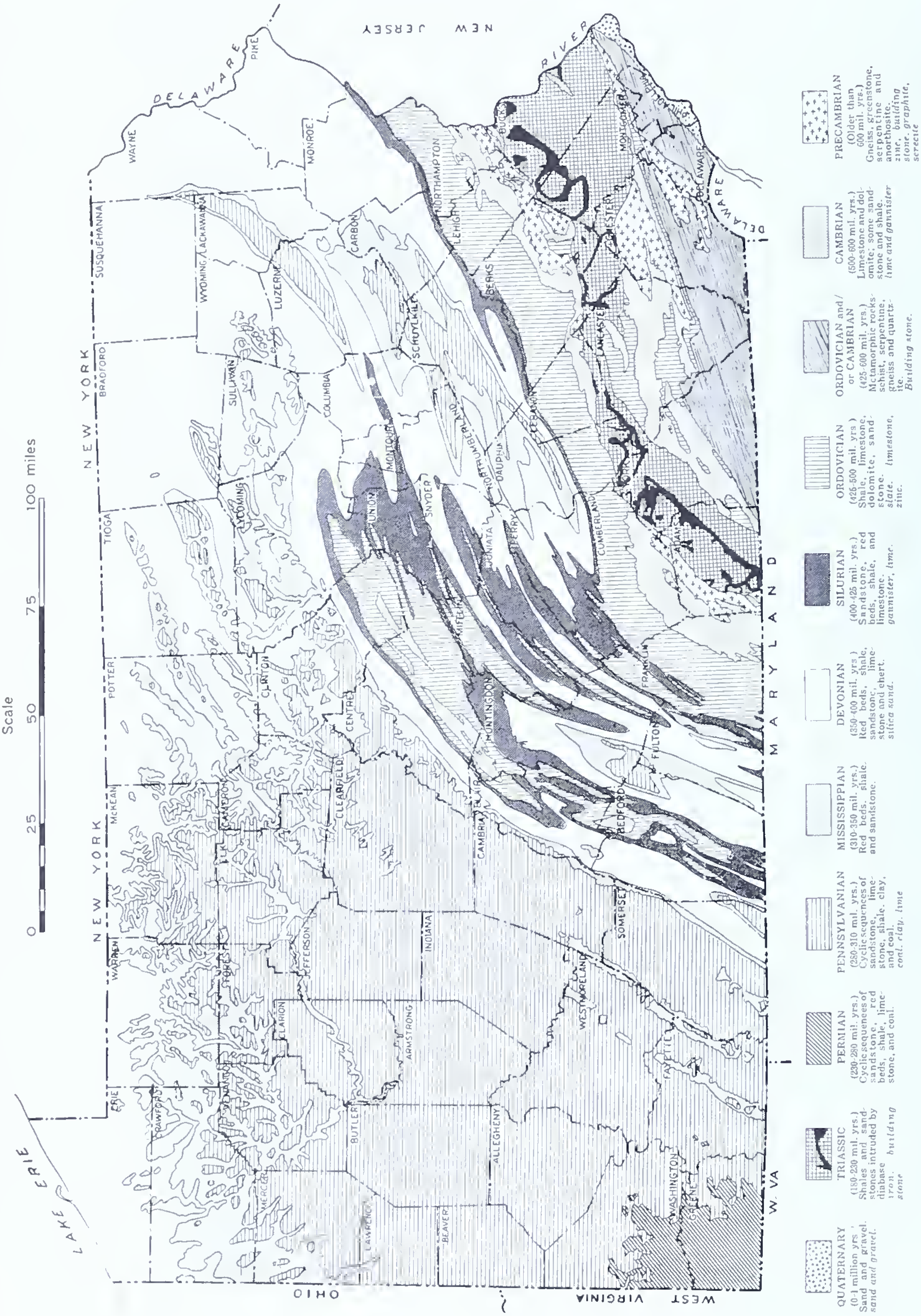


Figure 2. Geologic map of Pennsylvania.

ceramic use. Ceramic testing of a 4.5 foot channel sample of a stony anorthosite residual soil collected from a trench at Rockville, Chester County, indicated this material could not be used as the principal ingredients of a vitreous clay product. Continued prospecting in this area may outline a reasonable acreage of residual clay devoid of coarse material suitable for ceramic use. A feldspar pegmatite residual clay sample, collected from a clay pit stockpile located 0.4 mile southwest of Kaolin, Pa., was tested and is recommended for flue liner and low duty refractory use. Depth of workings in the pit indicates the clay is probably between three and five feet thick and is best developed in proximity to the local drainage system. A drilling program would be necessary to determine the amount of reserves.

There are very few Cambrian shale units in southeastern Pennsylvania. Results of testing for ceramic uses on samples of the Kinzers Formation in this portion of the State, suggest that it is one of the more important units for use in manufacturing lightweight aggregate by the rotary kiln method. The Kinzers Formation may locally be a dolomite, limestone, shale, sandstone, or combination of these lithologies, but everywhere it is divisable into a lower shale member, a middle carbonate rock member and an upper calcareous sandstone member. In the more eastern exposures, especially east of Lancaster, Pa., the formation consists mostly of carbonate rock. In the vicinity of Lancaster and westward there are more shale and sandstone units in the formation than carbonate rock. Locally the shale is tightly folded and cleavage is so well developed that the bedding is obliterated; in some areas the shale beds have been altered to a fine-grained micaceous phyllite.

Three Ordovician formations that have been sampled are: the Hershey Formation, the Cocalico Formation, and the Martinsburg Formation. The Hershey Formation is believed to be equivalent to the "cement rock" facies of the Jacksonburg Formation (MacLachlan, D. B., 1967, p. 60). Ceramic tests on a sample of Hershey Formation residual clay, collected from a stream bed in the vicinity of Wernersville, Pa., indicate potential for use in face brick and structural tile manufacture. Field relationships suggest this sample may be part of an extensive residual clay deposit.

The Cocalico Formation which has a fair potential for use in lightweight aggregate production, crops out only in the Lancaster County portion of the Piedmont province, and is probably equivalent to the Martinsburg Formation. However, there is a distinct difference in lithologic appearance between the Cocalico and the Martinsburg Formations. The Cocalico Formation consists of blue, green, and purple, thin-bedded to fissile shales intercalated with arkosic (feldspathic) sandstone containing glassy quartz grains. The shale has well-developed cleavage and weathers rapidly to a soil containing thin, buff-colored shale slivers. The

Martinsburg consists of a lower black to gray, carbonaceous, fissile shale and an upper yellow-green sandstone. East of the Lehigh River much of the shale has been altered to slate. The Martinsburg shale weathers easily, but the slate has a greater resistance to weathering. The Martinsburg Formation in Pennsylvania was sampled from Franklin County at the Maryland border to Northampton County at the New Jersey state line. Many samples of the Martinsburg Formation submitted for ceramic evaluation have been reported acceptable for the manufacture of face brick, decorative brick, stoneware (pottery), floor tile, rotary kiln lightweight aggregate (fair to excellent in quality), and possibly sintered aggregate.

Rock units of Silurian through Permian age do not occur in southeastern Pennsylvania. However, the Devonian Mahantango Formation in Franklin and Schuylkill Counties, and some residual clay resulting from weathering of Devonian rock in Monroe County immediately north of this region, have been sampled, tested, and incorporated into this report. The clay samples are associated with the New Scotland, Ridgeley, Schoharie-Esopus, and Buttermilk Falls Formations.

The Mahantango Formation crops out throughout most of central Pennsylvania and is essentially lithologically uniform—a clayey or finely arenaceous shale to fine-grained shaly sandstone which may be platy or flaggy locally. The Mahantango weathers into polygonal chips, pencil-shaped fragments, irregular blocks, or occasionally thin, sandy plates; spheroidal weathering is common in the clayey shales. All Mahantango Formation samples in this study were collected from its most eastern outcrop belt. Rotary kiln testing reports for samples from Franklin and Schuylkill Counties indicate the Mahantango is an excellent raw material for lightweight aggregate.

The New Scotland Formation is a calcareous shale with lenses of argillaceous limestone and with some chert at the base of the formation. Where deeply weathered, the New Scotland Formation yields a fine-grained and siliceous residual white clay. A sample of the white clay was collected from a prospecting trench excavated normal to the strike of the relic bedding at the Universal Atlas Cement Company's clay pit near Kunkletown, Pa. Tests on this sample indicated the material should be useful in the production of stoneware and possibly flue liners and low duty refractories.

A sample of residual clay resulting from the weathering of the upper part of the Ridgeley Formation and lower portion of the overlying Schoharie-Esopus Formation was collected from an abandoned clay pit located southwest of Kunkletown, Pa. The sample varied from a clay to a semi-plastic clayey shale which is considered useful as a raw material for face brick manufacture.

Two samples of Buttermilk Falls Limestone residual clay from Monroe County were collected for the present study. Ceramic tests indicated this clay may be used to manufacture flue liners or stoneware and low duty refractories. Large deposits of clay result from weathering of argillaceous facies within synclines by the intensified leaching action of optimum ground-water circulation through the limestone.

The Triassic sedimentary deposits in Pennsylvania belong to the Upper Triassic Newark Group. The Newark lithologies comprise a great thickness of alternating shale and sandstone with subordinate siltstone, conglomerate, and arkose. The Triassic rocks sampled in this study are: Stockton, Lockatong, Brunswick, New Oxford, Gettysburg, and Hammer Creek Formations. Many of the Triassic rock samples tested proved acceptable for such ceramic uses as face brick, decorative brick, structural tile, sintered aggregate, and rotary kiln lightweight aggregate. Four Lockatong Formation samples collected in Bucks County are considered excellent raw material for rotary lightweight aggregate.

UNITS PREVIOUSLY ANALYZED IN SOUTHEASTERN PENNSYLVANIA

Some rock units, or their residual deposits, in southeastern Pennsylvania, sampled in the previous investigation of this series (See O'Neill and others, 1965), were not sampled in the present study. The majority of these units are either Cambrian or of probable Lower Paleozoic (Cambro-Ordovician) age and are from the Piedmont province. The Chickies Formation sampled in Lancaster and York Counties is a thin to thick bedded, light colored, vitreous quartzite, frequently with beds of sericite schist and slate. The upper part of the formation is thin bedded, and in places disintegrates into a fine, white siliceous clay. All samples tested were residual clay. Some deposits of clay are up to 60 feet thick and locally contain sandy layers and quartz veins.

The Harpers Formation, sampled in Cumberland and York Counties, is composed chiefly of phyllite and quartzite. A sample collected from Cumberland County is a residual clay probably formed by deep weathering of thin-bedded quartzite and phyllite; the York County sample is a reddish-brown residual clay containing fragments of phyllite. The Cumberland County deposit is being exploited as a portland cement whitener but is suitable for making decorative brick and tile; the York County deposit is being used to make face brick. Laboratory tests of the York County sample for ceramic purposes indicated that it is a nonplastic clay containing a significant amount of sand and silt size material, and should be blended with another clay for brick making purposes.

Samples of residual clay in Lancaster County resulting from the weathering of the Ledger Formation have been tested for ceramic uses. The Ledger Formation is a granular, gray to white dolomite, generally thick-bedded, with massive dark blue to mottled dolomite at the top of the formation. Upon weathering, it yields a deep red, granular clay soil. A sample of Ledger residual clay collected from a quarry located 0.5 mile east of Rohrerstown, Lancaster County, is considered to be a potential raw material for producing brick, tile, and possibly sintered aggregate. A second sample of Ledger residual clay was collected about 1.2 miles east of Gordonville, Pa. This sample was a sandy clay and, although it tested negatively for ceramic uses, it is considered an excellent pigmenting material.

A sample of residual clay from the Conococheague Group collected in Berks County was found to be plastic and usable as a raw material for brick making and possibly as a pigmenting clay.

A sample of Peach Bottom Slate collected 1.4 miles north-northwest of Peach Bottom, Lancaster County, and subjected to quick-firing bloating tests, produced a bloated product with fair crushing and drying characteristics. Bloating tests suggest a possible use of the Peach Bottom Slate as a sintered aggregate raw material. A sample of schistose Peach Bottom Slate was collected from a quarry located one mile northeast of Delta, York County. Laboratory tests suggest it would be an acceptable raw material for making sintered aggregate.

A medium light gray to medium gray graphitic clay, probably a weathered product of the Wissahickon Schist, was collected from a quarry located 0.1 mile south of Hokes, York County. The clay was moderately plastic but slightly gritty, had very low dry strength, and fired between cone 19 and 23 P. C. E. The potential uses for this clay are for low duty refractory products and possibly chimney flue tile or paint filler.

A Conestoga limestone residual clay was collected from the Lancaster Brick Company quarry located 1.5 miles northwest of Lancaster, Pa. The clay, up to 15 feet thick, is only slightly plastic and has low dry strength. Firing tests suggest that it is a potential brick clay.

A sample of an Illinoian terminal moraine deposit from near Wescosville, Lehigh County, was evaluated for ceramic uses. The deposit consists of a clay matrix with fragments and boulders of shale and carbonate rock. It is estimated that the clay constitutes 80 percent of the deposit. The material was moderately plastic, possessed low dry strength, and test bars expanded and began to melt at 2,200° F. The material is considered to be useful for making brick and tile. More detailed and selective sampling of glacial deposits in Lehigh and Northampton counties may outline several lightweight aggregate deposits of commercial size.

CLAY PRODUCTION IN SOUTHEASTERN PENNSYLVANIA

Since chimney brick and pottery manufacturing began in the Philadelphia area during early colonial days, the clay industries of southeastern Pennsylvania have contributed ever increasingly to the economy of the region. To the soft alluvial clays used in the industry's infancy have been added the large production and reserves of consolidated rock requiring complex mining and processing methods. A comparison of recent tonnages and dollar values generated by the clay industries and their relationship to the Gross National Product is depicted in Figure 3.

Every county in southeastern Pennsylvania has ceramic clays and shales within its boundaries and all counties have at some time produced ceramic products from native materials. Miscellaneous clays, fire clays, and kaolin clays are all produced in this area (Table 1). Statewide miscellaneous clay and shale accounted for 52 percent of the total production in 1967 and Berks County was among the top three leading producers. The miscellaneous clays are used in producing structural clay products, especially face brick, lightweight aggregate and portland cement. The remaining tonnage is used in producing stoneware and filler material.

The annual production of fireclay in southeastern Pennsylvania is comparatively small, but it is used in the manufacture of products and component mixes having high unit value such as the foundry and steel industries. Perennially Lancaster and Montgomery Counties are the major producing areas of fire clay, but Schuylkill County in some years has produced more tonnage than the other southeastern Pennsylvania fire clay producing counties combined.

Kaolin clays are produced in Lancaster and Cumberland Counties with Cumberland County being the leading producer in the State. Chester County at one time had many clay pits producing kaolin clays but no production has been reported for over ten years. The major portion of kaolin clay produced is used as the argillaceous fraction of the white portland cement mix; the remainder of the annual production is used in the refractory industry and for nonceramic filler use.

In addition to the non-ceramic filler material produced from the kaolin deposits, sericite-schist operations in Cumberland and Adams counties contribute substantially to the wealth of the region. Presently, only crude sericite schist is being produced in Adams County and processed for use as a carrier in insecticide chemicals, as a filler in asphalt, enamel coating, and joint cement.

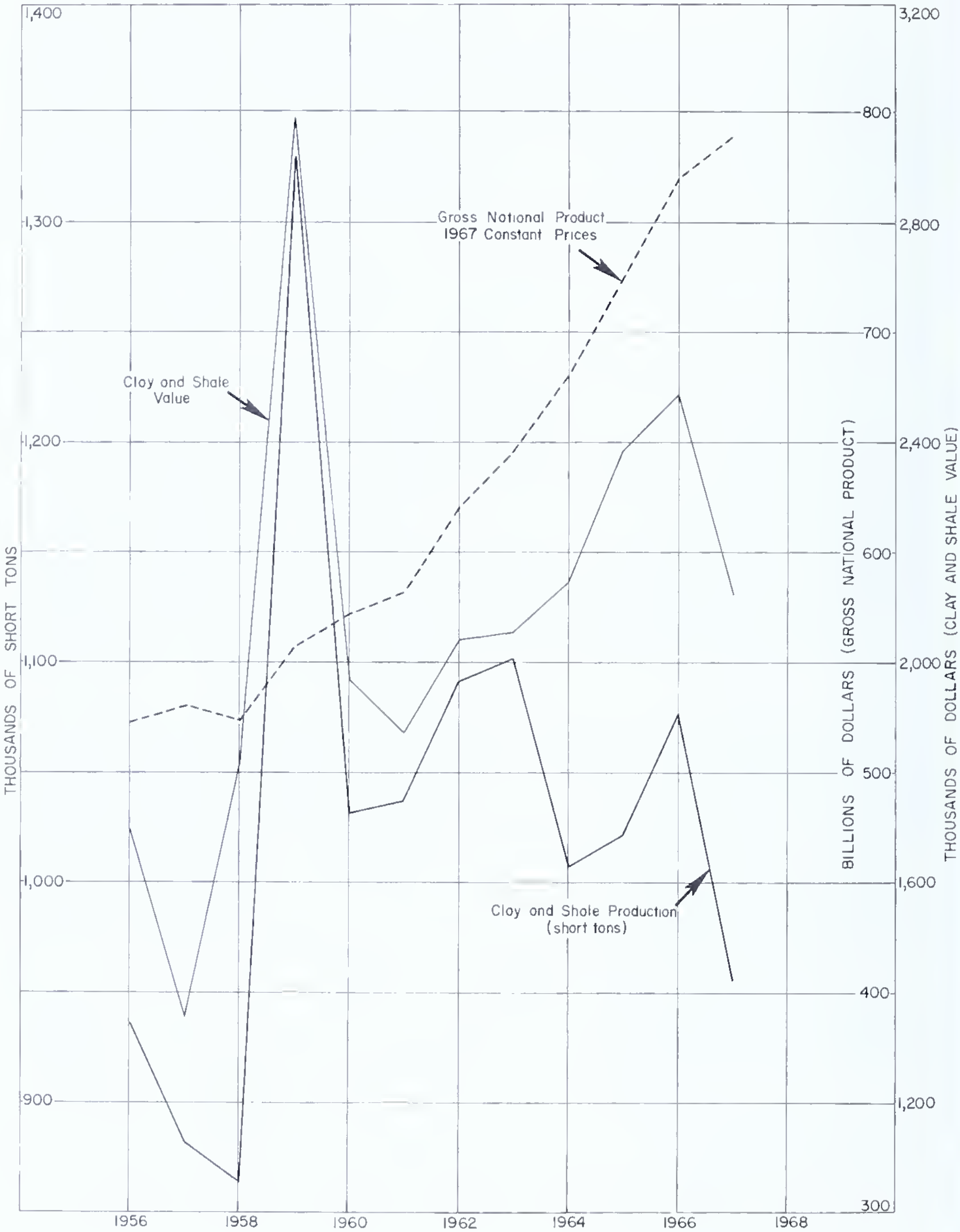


Figure 3. Clay-shale production values versus gross national product for southeastern Pennsylvania (1956-1967).

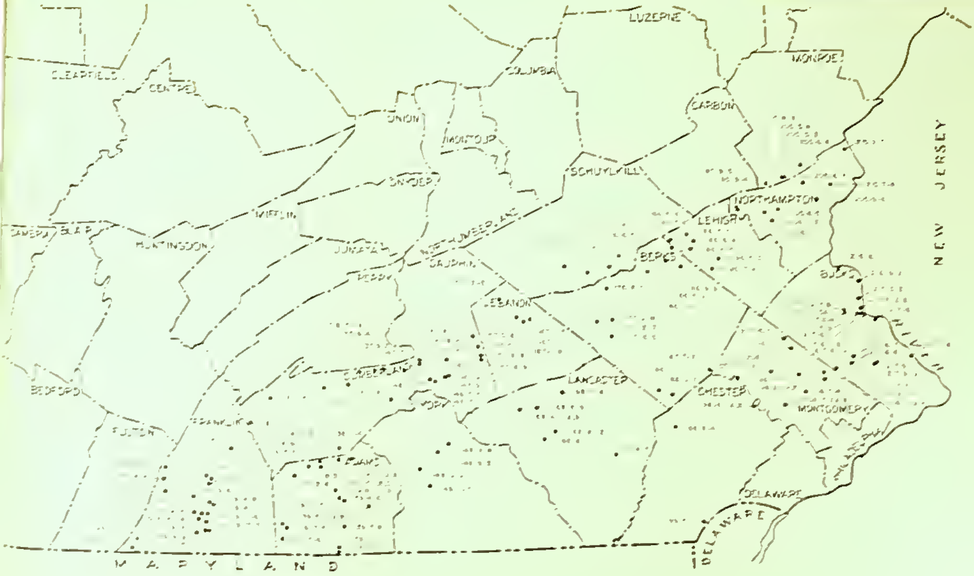


Figure 4. Map of sample locations for southeastern Pennsylvania.

Table 1. *Types of Clays and Shales Produced in Southeastern Pennsylvania, 1956-1967.*

		Miscellaneous Clays				
	Fireclay	*Heavy Clay Products*	*Stoneware*	*Portland Cement*	*Others*	*Kaolin*
Adams		X			X	
Berks		X				
Bucks		X				
Chester		X				
Cumberland	X					X
Dauphin	X	X				
Delaware						
Franklin						
Lancaster	X	X				X
Lehigh						
Lebanon						
Monroe						X
Montgomery	X	X	X		X	
Northampton						
Philadelphia						
Schuylkill	X	X		X		
York		X		X		

SAMPLING AND TESTING PROCEDURES

GENERAL STATEMENT

The sampling of shales and clay materials was initiated to evaluate the argillaceous geologic units of southeastern Pennsylvania for commercial exploitation, especially as ceramic raw materials. During the course of the investigation 19 geologic units and their varying lithologies were sampled on a crude geographic grid, for a total of 159 samples. The general locations for the 159 samples are shown in Figure 4. A detailed location description for each sample is included in the Sample Data and Test Results section of this report.

The methods used in this investigation were patterned after those established for the initial phase of this continuing clay-shale investigation program (O'Neill and others, 1965). The samples were collected from natural exposures, road cuts, excavations, and quarries. Samples were submitted to the U. S. Bureau of Mines Norris Metallurgy Research Laboratory, Norris, Tennessee, and to the U. S. Bureau of Mines Tuscaloosa Metallurgy Research Laboratory, Tuscaloosa, Alabama, for ceramic use evaluation. All rotary kiln tests were performed by the Tuscaloosa Research Laboratory.

SAMPLING TECHNIQUES

The field sampling program was carried out in two phases. The first phase consisted of selecting the sampling site based primarily on the potential of the site for commercial exploitation. Factors taken into consideration were: availability of utilities (rail and highway transportation, electric power, and natural gas lines), adequate source of industrial water, potential labor force, and quarry land acreage versus urban real estate. After selection of a sampling site, a 10 pound sample (called gross sample) of one of the following sample types was collected: grab, composite, or channel. Each sample location and number was plotted on a topographic map and notes were made concerning the local geology, lithologic description of the sampled material, and the economic feasibility of the site.

The gross sample was returned to the Harrisburg offices of the Pennsylvania Geological Survey where a representative fraction of each sample was placed in the Pennsylvania Geological Survey clay and shale library as reference material. The remainder of the sample was submitted to the U. S. Bureau of Mines for testing and evaluation (see O'Neill and others, 1965, pp. 11-19, for detailed discussion of tests performed and types of potential uses). The U. S. Bureau of Mines laboratory prepared a 100 gram, ground (powder) sample of each gross sample submitted and returned it to the Pennsylvania Geological Survey. Aliquots of these powder samples were chemically analyzed by commercial laboratories and quantitatively X-rayed by the Pennsylvania Geological Survey.

The gross samples which showed a potential use for lightweight aggregate were then channel sampled to obtain two duplicate samples (called bulk samples) each weighing approximately 200 pounds, for processing through a pilot plant size rotary kiln for lightweight aggregate evaluation.

CLAY EVALUATION

General Discussion

Clay is the major and often the only raw material used in the manufacture of a wide variety of ceramic products. For statistical purposes, the Bureau of Mines groups clays in six classifications: kaolin, ball clay, fire clay, bentonite, fuller's earth, and miscellaneous clay. The samples described in this report fall in the miscellaneous classification which includes stoneware clays, common clays, and shales. The 1967 production of miscellaneous clay in the United States was 39.3 million tons (U. S. Bur. Mines, 1968, Table 10, p. 326-327). 18.9 million tons of the production went into building brick, structural tile, and sewer pipe; 11.1 million tons into cement; and 8.8 million tons into lightweight aggregate.

Because most clays falling into the miscellaneous category were sedi-

mentary in origin, their mineralogical compositions vary widely. Quartz, mica, and iron-bearing materials are mixed with clay minerals in nearly all deposits. The ratio of clay minerals to impurities and the degree of consolidation are reflected in the ceramic properties (see succeeding discussions). Many are hard and low in plasticity while others are soft and very plastic. Some will fire to vitrification without trouble while others will melt suddenly without warning. The fired colors range from buff to dark red and brown.

In general the samples tested in this investigation hold very little promise for use as raw material for other than structural clay products or for lightweight aggregate made by the rotary kiln method. A few selected samples indicated either promise or doubtful use for refractory clays, sintered lightweight aggregate, stoneware, clay additive, or non-ceramic filler material.

The following discussions relate to laboratory procedures used by the U. S. Bureau of Mines Tuscaloosa Metallurgy Research Laboratory. Techniques and interpretations vary in some respects from those practiced at the U. S. Bureau of Mines Norris Metallurgy Research Laboratory. In the interest of comparison one should refer to Physical Tests by R. D. Thomson (O'Neill and others, 1965, p. 11-19) for a summary of methods and interpretations employed by the Norris laboratory. Figure 5 is a flow sheet for the Tuscaloosa Laboratory. Table 2 is a comparison of major ceramic product nomenclature variations between the two laboratories. It is noted in the individual sample data whether Norris or Tuscaloosa Metallurgy Research Laboratory performed the preliminary tests. All rotary kiln tests for lightweight aggregate evaluation were performed by the U. S. Bureau of Mines Tuscaloosa Metallurgy Research Laboratory.

A more comprehensive description of methods used in testing ceramic raw materials are described in U. S. Bureau of Mines Bulletin 565 (Klinefelter, 1957). The more important A. S. T. M. specifications and tests related to structural clay products and refractories are listed in the References.

Preliminary Tests

The tests used in making preliminary appraisals of raw materials for heavy clay products are exploratory in nature. Results of the preliminary tests delineate inherent ceramic properties of the clay and indicate whether or not more comprehensive tests are warranted.

The flow chart followed in making preliminary evaluations of clays and shales is shown in Figure 5. A 2-pound representative sample of the material is dried at 230°F and ground to pass a 20-mesh sieve. One hundred grams of the powdered clay is tempered with water to form a plastic mass. The water of plasticity and the workability are noted. Small test specimens (1½ by 2½ by ¼ inch) are formed in a steel mold, and

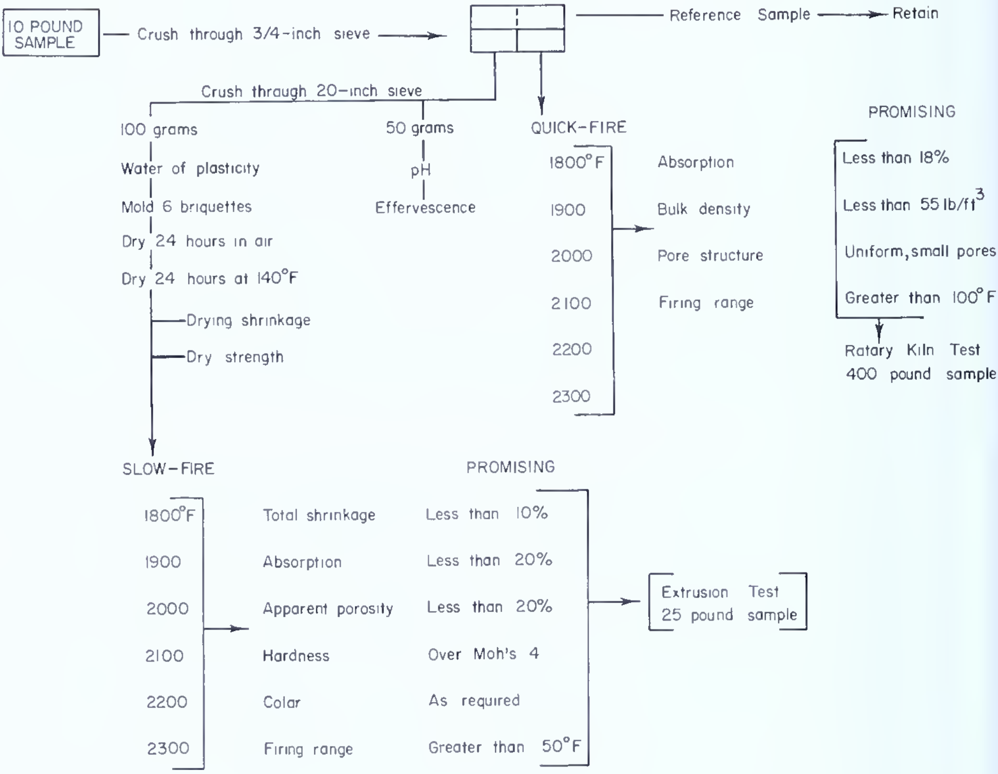


Figure 5. Flow chart for preliminary evaluation of clays and shales.

after being marked for shrinkage, are dried overnight at 140°F. Six of the dried specimens are placed in a laboratory kiln, and the temperature is raised to 1,900°F in about 4 hours. Test specimens are removed from the kiln at 100°F intervals from 1,800 to 2,300°F after a 15-minute soak at each temperature. About 4 hours are required to cover the range from 1,800 to 2,300°F in an electric kiln fitted with silicon carbide heating elements. This range includes most of the firing temperatures prevalent in the structural clay products industry, but the top temperature is not high enough to adequately evaluate refractory products.

From the preliminary tests, the following data were collected: characteristics of the unfired material including color, pH, water of plasticity, workability, drying shrinkage and dry strength; characteristics of the fired material including total shrinkage, color, hardness, absorption, apparent porosity, bulk density, and bloating tendency. The bloating tendency is determined by quick-firing (see lightweight aggregate section) a few ½-inch lumps of each material at 2,100°F.

Table 2. *Comparison of ceramic product nomenclature used by Norris, Tenn., and Tuscaloosa, Ala., U.S.B.M. Laboratories.*

	Norris, Tenn. U.S.B.M. Laboratory	Tuscaloosa, Ala. U.S.B.M. Laboratory
Face Brick	Face Brick	Face Brick (MW, SW, NW)
	Common Brick	Building Brick
	Outside Brick	
	Regular Brick	
	Brick	
Decorative Brick	Architectural Brick	
	Terra Cotta	
	Inside Brick	
	Soft Brick	
Structural Tile	Hollow Tile	
	Drain Tile	
	Drain Tile	Structural Tile
	Wall Tile	Glazed Structural Tile
	Sewer Tile	
	Structural Tile	
	Tile	
Floor Tile	Floor Tile	Quarry Tile
Flue Liner	Flue Tile	Flue Lining
		Flue Tile
Low Duty Refractory	Low Duty Refractory	
Lightweight Aggregate		
Rotary		
Fair	Fair	Marginal
Good	Good	Promising
Excellent	Excellent	Promising
Not Promising		Not Promising
Sinter	Sinter	Sinter
Positive Bloat	Positive Bloat	Positive Bloat
Stoneware	Stoneware	Stoneware
	Pottery	
	Artware	
	Outside Pottery	
No Designated Use	Ceramic—None	Not Promising
	NONE	NONE (Ceramic) not suitable for use in vitreous clay products
		Not suitable for use as the principal component in vitreous clay products

As a rule, the information obtained from the preliminary tests is adequate for general appraisal, although the numerical results obtained in the laboratory will vary to some extent from those obtained when the same material is processed on an industrial scale. It should be noted that each evaluation reported in this investigation is based on one small sample that may not be typical of the entire deposit or formation.

Structural Clay Products

Structural clay products are commonly formed by stiff mud extrusion. The ideal clay would have moderate plasticity with good workability, high-dry strength, a long vitrification range, total shrinkage of more than 10 percent and a fired color to please the market. Because few clays or shales are ideal in all properties, it is often necessary for the manufacturer to develop blends fitted to his process and product.

Lightweight Aggregate

The process of expanding clays, shales, and slates in a rotary kiln to produce lightweight aggregate for concrete was patented by Stephen Hayde in 1917; however, demand for the product was limited and the industry did not begin to expand until the construction boom following World War II. According to U. S. Bureau of Mines statistics about 4 million tons of miscellaneous clays were used nationwide for the manufacture of lightweight aggregate during 1956; this figure had increased to nearly 9 million tons in 1967. It is anticipated that growth during the next ten years will parallel the growth in Gross National Product.

Several factors contributed to the rapid increase in lightweight aggregate production over the eleven year span 1956-1967 but the most important single factor was undoubtedly the improvement in quality and uniformity of material delivered to the consumer. In early years control over the raw materials and the processing was minimal; as a result, much of the aggregate entering the market was of poor quality. Today all steps in manufacture are closely controlled. Bloating properties of the raw materials are determined well in advance of mining. The kiln feed is carefully sized and the firing temperature is kept under constant surveillance. In addition, the size gradation of the product is adjusted to meet both A. S. T. M. specifications and those of the consumer.

The use of controls over each stage in the process makes it possible for the manufacturer of lightweight aggregate to deliver a uniform product having the following unique properties:

1. Lightweight—Depending on the aggregate and the strength required, concrete with lightweight aggregate will weigh from 90 to 115 pcf (lb./cu. ft.). In contrast, sand and gravel concrete weight about 150 pcf.
2. Strength—In a properly designed mix, lightweight aggregate will produce concrete that develops 5,000 psi (pounds per square inch) compressive strength in 28 days.

3. Toughness—The modulus of elasticity of lightweight concrete is about one half that of heavy concrete; as a result it is tougher and more shock resistant.
4. Insulation—In thermal insulating value, an 8-inch thick wall of lightweight block is equal to a heavy concrete wall 34 inches thick.
5. Stability—Well fired lightweight aggregate is chemically inert; it will not cause iron staining and it is not attacked by salt water.

About 80 percent of the expanded clay aggregate produced in the United States is used in masonry units; the remaining 20 per cent is used in structural concrete for such diverse applications as pre-cast floor and roof slabs, tilt-up wall panels, bridge decking and airport runways.

Preliminary (Quick-Firing) Tests

Lightweight aggregate is produced by expanding clay or shale in a rotary kiln or by sintering on a moving hearth.

Clays that bloat between 1,800° and 2,200°F are preferred for rotary kiln processing. A long temperature range between initial bloating and melting is required; a range of 100°F is generally considered essential for rotary kiln processing. The shales should crush to irregular lumps with no flaking. Fines generally cause ring formation in the kilns so they must be removed from the feed. As a result, the minus 4 mesh material should not exceed 20 percent. The expanded particles should have a strong cell structure and a vitreous outer shell.

In the sintering process, clay fines are mixed with a combustible material and pelletized for firing on the moving hearth. The clay should vitrify with slight expansion at a temperature of 2,000°F or below.

Quick-firing tests are used to determine the bloating characteristics of clays and shales within the range of commercial rotary kiln operating temperatures, starting just under bloating and continuing until overbloating or fusion.

A kiln preheated to 1,800°F is used in making the quick-fire tests. About a dozen ½-inch lumps of the material are placed in the furnace on a refractory boat; after 15 minutes at temperature the material is removed from the furnace. The procedure is repeated at 100° intervals to 2,300°F or until the material shows signs of melting. On the basis of quick-firing data, the material tested can be classified according to its potential for use in the manufacture of lightweight aggregate as follows: (also see Table 2)

Promising—A material characterized by good cell structure encased in an impervious shell; one that will produce a coarse aggregate weighing less than 55 pcf, at a temperature not over 2,200°F and has a processing range of at least 100°F between initial bloating and overbloating.

Marginal—A clay that will bloat to specifications, but is refractory; one that may be a mixture of bloating and nonbloating materials; one that appears to have a short bloating range, or has poor crushing characteristics.

Not suitable—Materials that are nonbloaters; those high in lime, and those having a poor cell structure.

The quick-fire tests give data useful in appraising clays or shales as raw materials for lightweight aggregate, but the final evaluation must be based on data obtained from tests designed to approximate commercial operating conditions.

Rotary Kiln Tests

Bulk samples (300 to 400 pounds) are spread in trays and dried overnight at 160°F. The dried samples are crushed in a swing hammer mill to pass a ¾ inch sieve. Minus ¾ inch, plus 4-mesh material is used as kiln feed; the minus 4-mesh is rejected as crushing loss.

A gas-fired rotary kiln 14 feet long, having an inside diameter of 16 inches, is used for testing samples found to be promising for lightweight aggregate in the preliminary tests. Tests are run with the kiln inclined on a 2° slope and rotating at 3 rpm. Raw material is charged at a rate of about 100 pounds per hour. The temperature of material passing through the hot zone is determined by an optical pyrometer.

The kiln is heated to the temperature indicated in preliminary tests that is required to produce aggregate weighing between 55 to 65 pounds per cubic foot. The temperature is raised gradually until the loose-pour weight of the uncrushed bloated material is in the range of 40 to 45 pounds per cubic foot. This temperature is maintained until about 150 pounds of expanded material is produced, then the temperature is raised until sticking commences; this temperature is the upper limit of the firing range.

One half of each expanded sample is crushed to pass a ¾ inch sieve and is then separated on stacked screens into the size fractions required for coarse aggregate. The other half of the sample is crushed to pass a ⅜ inch sieve and is separated into the size-fractions required for fine aggregate. Screen analyses and loose-pour weights of each fraction are reported.

The sized aggregate must be tested in lightweight concrete before final evaluation can be made. There were no lightweight concrete tests made on the samples reported upon in this investigation.

Cement

Portland cement is a clinkered mixture of an argillaceous material and a calcareous material. The argillaceous material is usually clay, shale, or slate. The calcareous material may be limestone, cement rock, or marine shells. Roughly, the stone to clay ratio is about 3 to 1. Frequently, mill scale is added to adjust the mix to approximate the equation:

$CaCO_3$ required $= 4.1\ SiO_2 + 2.6\ RO_3$ (two parts alumina to one of iron oxide) by weight.

Raw materials that contain variable amounts of magnesia, gypsum, and pyrite are not desirable. The chemical composition of the argillaceous materials used in cement must complement that of the calcareous rock. The only tests required for preliminary evaluation are chemical analyses. The chemical analyses for the individual samples tested in this investigation indicate those that have potential use in portland cement manufacture.

QUANTITATIVE X-RAY MINERALOGY

General Statement

The quantitative analysis of the mineralogy of clays and shales in southeastern Pennsylvania is a continuation of the previously published (O'Neill and others, 1965) general study of the economic potential and character of argillaceous units in Pennsylvania. There are two important reasons for continuing such quantitative mineral analysis: (1) to correlate mineral content with potential use to provide useful criteria for future exploration, and (2) to obtain basic data concerning mineral variation in Pennsylvania clay and shale units. Any binary correlation between use and mineral variation will be approximate because other variables such as raw material blending, texture, grain size, physical properties, and chemical constituents will exert a significant influence upon the utility of a clay or shale. To facilitate the interpretation of analytical data (mineral, chemical, physical, and geological information), a computer program is being initiated to handle correlations of the numerous and complex variables. Certain mineral components are influential (Lapham and Jaron, in O'Neill and others, 1965, p. 410-422), and quantitative mineral limits for specific rock types and uses can be defined, even though imprecisely.

To expedite the rapid analysis of a large number of samples, mineral analysis by X-ray methods must be modified, yet must retain an accuracy sufficient to make useful correlations with economic potential and geologic unit. The analytical techniques previously used (Lapham and Jaron, 1964; Lapham in O'Neill and others, 1965, p. 21-30) have been slightly modified and extended for greater accuracy and to obtain a more broadly based knowledge of the fundamental problems involved in polycomponent mineral analysis.

General Analytical Problems

The general problems of quantitative mineral analysis by X-ray methods have been discussed in detail in the previously published report (see Lapham in O'Neill and others, 1965, p. 21 to 25). The major problems are differential X-ray absorption among the samples, differences in reflectivity resulting chiefly from variation in grain orientation and grain size, degree of crystallinity (particularly in the mica and clay minerals), and adequate instrument standardization control.

In order to increase the accuracy of intensity measurements, improvements were made in the standardization methods of the Norelco horizontal axis goniometer diffractometer. Throughout the project, a standard silicon disc was used to measure constancy of instrument intensity. The intensity of the major silicon reflection was recorded at the beginning and end of each day's running session, using both known sample mixtures (i.e., prepared mineral mixtures) and clay-shale samples. All intensities were recalculated to an arbitrary standard intensity for silicon. Variability greater than about 10 percent was considered too great for correction, and samples run under these conditions were re-run after instrument realignment. The standard Silicon disc runs were made at the same instrument settings as the samples: $1°2\theta$ per minute (2° per inch on the diffractometer chart), a scale factor of 8, a multiplier of 1.0, a time constant of 4, and 1° slits.

Another instrumental problem is that of interference; i.e., overlapping of X-ray reflections. This problem was treated in the same manner as described previously (op. cit.). Both K and Na-Ca feldspars were treated together as total feldspar. In order to separate kaolinite intensities at 7.1 Å, a combined chlorite-vermiculite-montmorillonite component was subtracted by assuming that the ratio of intensities of chlorite-vermiculite-montmorillonite at 14Å to that at 7 Å was about 1:1. Where the vermiculite component is high, as in a highly weathered shale, too great an intensity will have been subtracted from the kaolinite 7 Å reflection, resulting in too low a reported kaolinite percent. Where the chlorite component is high, or vermiculite is absent, the kaolinite percent will be anomalously high. This will be especially true if the chlorite is a high iron variety. Since the 14 Å peak is used to obtain the 7 Å kaolinite peak intensity, a ratio of 4 chlorite to 2 vermiculite to 1 montmorillonite is assumed to approximate the largest number of unknowns analyzed yielding an intensity subtraction of about 1:1. Where these three components (chlorite, vermiculite, or montmorillonite) could be clearly distinguished, appropriate corrections were made in the intensity subtraction for kaolinite. Using this rapid, but appropriate, method, kaolinite percentages are the least accurate. In gen-

eral, X-ray reflection interference results in mineral percent curves which do not originate at zero intensity (see Figure 6), but which may have an initial intensity at zero mineral percent.

Structural line broadening yields lower peak heights (Lapham in O'Neill and others, 1965). Line broadening of kaolinite is considered to be insignificant and within the limit of error for the rapid, quantitative methods used in this study. The problem of line broadening in mica is discussed separately, since modifications have been made in the technique as originally described (op. cit.). Grinding below 325 mesh was also kept to a minimum in order to prevent mechanical line broadening from decreasing crystalline size and to obviate the destruction of clay mineral lattices.

Matrix absorption and orientation have not been completely eliminated by back filling of the sample holder and thorough mixing, with the result that mineral percent curves are somewhat sinusoidal rather than strictly linear (see Figure 6). When the matrix changes so that it is predominantly monomineralic, or conversely, when one mineral component reaches a minimal limiting amount, the slope of the mineral percent curve changes to a more shallow gradient. At such flexure points in the curves a small error in percent determination will result, on the order of 3 to 5 mineral percent in addition to the stated percent error (Table 4). However, the additional number of standard mixtures used in this study has allowed a greater definition at these critical points than was possible in the original investigation (op. cit.).

Quantitative Analysis of Mica

The Problem of Line Broadening

The problem of quantitative analysis of mica (Lapham and Jaron, 1964; Lapham in O'Neill and others, 1965) will be only briefly mentioned here. Standard mica mineral percent curves based on mixtures containing well-crystallized 2M muscovite cannot be directly applied to micas in sedimentary rocks. Micas have different amounts of line broadening which irregularly decreases peak height. The peak is broadened more at the base than at half peak height. Because of this irregular broadening, a method was devised to measure angular peak width and to relate this width to a multiplier factor designated F_{mi}. F_{mi} is used as a multiplier of the raw average intensity in order to obtain a final raw average intensity that is a true measure of the amount of mica present.

Several modifications were made in this procedure from that used previously (op. cit.). The first modification was the recognition of two types of peak broadening: instrumental and mineralogical. Instrumental

line broadening is a geometric function that describes the change in angular peak width as the peak height (or intensity) changes. These changes result from changes in instrument alignment, from multiplier factors that result from different instrument settings, or from a slightly different kilovoltage. Instrumental broadening was determined in two ways: first from well crystallized 2M muscovite (pure and in mixtures) analyzed at different instrument intensities, and second, from measurements of the internal angle (a minimal angular breadth) of micas in sample unknowns. The internal angle is drawn so as to exclude line broadening at the peak base and to exclude shoulders or peaks. The two types of curves coincide exactly and result in an instrumental line broadening curve (Figure 6). This internal angle, if subtracted from the external total line broadening angle, will give the angular line broadening resulting from mineralogical effects. Because all the standard mixtures were composed of well crystallized 2M muscovite, all broadening in the study samples was instrumental and the F_{mi} multiplier of the raw intensity is 1.0. This instrumental curve (Figure 6) was used to correct the measured total angular line breadth for standards and unknowns. This correction in angle was necessary because all intensities were recalculated to the intensity of a standard silicon disc; that is, changing the peak height intensity by recalculation must also change the angular width of a peak. The instrumental line broadening curve allowed such correction to be made complementarily with the silicon standard correction.

Angular Line Broadening Correction

The external mica line broadening angle, defined as the angle formed by drawing two lines from the apex of a mica peak to the base at each side, (including shoulders on the low 2θ side), in this report is referred to simply as the "mica angle". Utilizing the mica angle, several methods have been devised for determining the factor (F_{mi}) which must be multiplied by the average mica peak height intensity. In the summary of these methods, all intensities have been corrected to the arbitrary silicon standard intensity, and all mica angles have been correspondingly corrected for this new intensity by the geometric instrumental intensity curve of Figure 7. All of the methods used gave essentially the same F_{mi} curve. Minor adjustments were made to obtain a best fit, single, F_{mi} curve.

Theoretically there should be a family of mineralogical, or structural, line broadening curves similar in shape to the instrumental line broadening curve. Because structural line broadening is gradational, there would be an infinite number of such curves: but, until illites that present different degrees of line broadening can be separated, such a family of

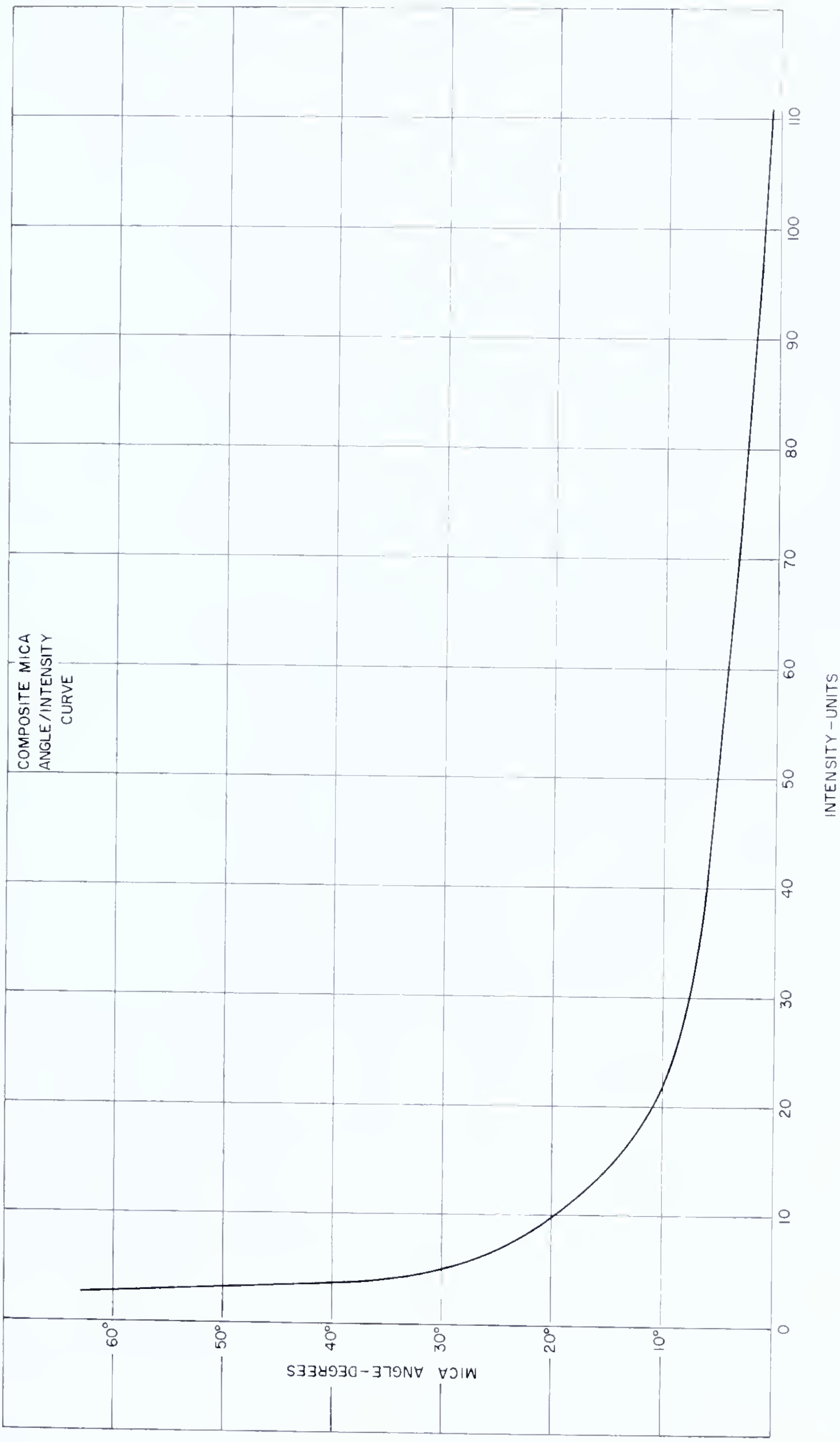
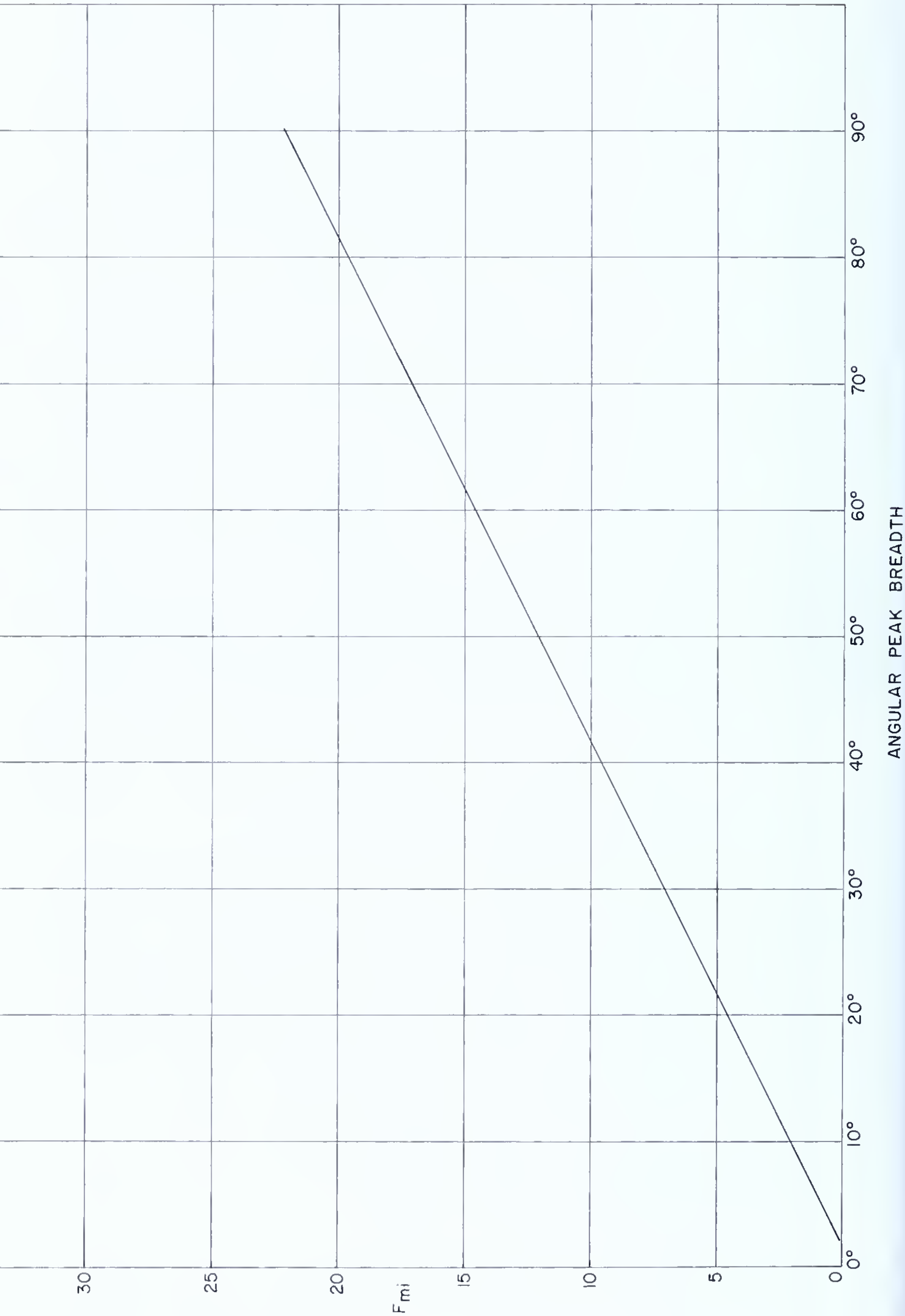


Figure 6. Instrumental line broadening curve.



0°
10°
20°
30°
40°
50°
60°
70°
80°
90°
ANGULAR PEAK BREADTH
0
5
10
15
20
25
30
F_{mi}

curves cannot be easily constructed. However, the significance of such a family of curves is notable. For each curve representing a specific amount of line broadening, there will be an F_{mi} curve, each with its own slope. Thus, the determination of any F_{mi} curve is at best an average for the extent of mineralogical line broadening present in the particular rock samples analyzed. For this reason, and because of varying instrumental intensities from instrument to instrument (or alignment to alignment), no single F_{mi} curve will have universal applicability. Thus, each researcher must construct his own F_{mi} curve. The greater the variability of mineralogical line broadening, the greater the inaccuracy, or range of error, for F_{mi} determination of quantitative mica percent. Because some samples deviate greatly from the average line broadening multiplier used in this report it became necessary, in order to obtain a more realistic mica quantification, to recalculate the percentage of mica on the basis of chemical analyses.

The simplest method for establishing an F_{mi} curve is to obtain end points. The pegmatitic 2M muscovite used in the standard mixtures has a multiplier that is theoretically 1.0 (after instrumental correction); i.e., there is no mineralogical line broadening of the mica. On the other hand, purified Fithian illite (from Fithian, Illinois, and obtained from Ward's Natural Science Est.) represents nearly the maximum amount of mineralogical line broadening found in field samples. From mixtures containing both pure 2M muscovite and pure Fithian illite, a plot of mica angle versus multiplier can be constructed. The F_{mi} of the 2M muscovite is 1.0, and that of the Fithian illite is the multiplier necessary to bring its intensity up to that of the pure 2M muscovite when each comprises 100 percent of the sample. Thus, it can be seen that the F_{mi} adjustment becomes an attempt to relate all mica intensities to that of well crystallized muscovite with no structural line broadening. Because of other factors (influence of grain size, absorption, etc.), the maximum F_{mi} end point of Fithian illite is only approximate. Methods discussed subsequently were used to more accurately define the F_{mi} slope.

Samples in which quartz and mica comprised 80 to 100 percent of the unknown were next used. In this method, the original quartz intensity-mineral percent curve is presumed to be unaffected by orientation, line broadening, and excessive fine-grained size effects. The amount of quartz was determined from the silicon-corrected mineral percent cure, and the amount of mica by subtraction from 80 to 100 percent. The multiplier necessary to bring the mica intensity of the mineral percent curve (established from the standards) into agreement with that of the known-percent (obtained by subtraction), is the F_{mi}. This was then plotted against the mica angle to yield points for the slope of the F_{mi} curve.

Because the previous method resulted in points only at low mica angles and low F_{mi} values, the curve was extended by using 50 unknowns containing the full range of mineral components. Utilizing the average intensity versus mineral percent curve obtained for all components (except mica) from the standard mixtures, the amount of mica was again obtained by subtraction. The mica intensity of the unknown was then divided into that of the standard curve at that mineral percent (as in the previous method). The resultant multiplier, the F_{mi}, was then plotted against mica angle. This procedure assumes that all original curves, except mica, are correct. Subsequent methods and tests indicated that this assumption is a good approximation. For this method, the scatter of points is larger because of other influencing factors. The slope of the final F_{mi} curve at this stage was slightly steeper than the Fithian illite end point seemed to indicate.

The final method is based on the asumption that quartz is essentially unaffected by line broadening, orientation, grain size, and absorption problems; that is, that the average silicon corrected quartz intensity curve is reliable. Two sets of quartz curves were plotted, one determined from the average intensity runs of the standard mixtures and the other after all mineral intensities were totaled and recalculated to 100. A multiplier (termed the quartz factor multiplier) was determined that would bring the calculated curve into agreement with the original average curve (Lapham and Jaron, 1964). The mica angle from the standard mixtures was then plotted against the multiplier necessary for that sample to result in agreement of the two quartz curves. These multipliers clustered around a factor of 1.0 and verified that there was no structural line broadening of the mica in the standards. A new standard mica curve was then constructed by multiplying the average mica intensities by the appropriate quartz factor multiplier. Using all unknown samples and the original mineral percent curves, excluding mica, the amount of mica was then obtained by subtraction. For the unknown samples, 90 to 95 percent total mineral components were assumed to have been determined, the remaining 5 to 10 percent being undetermined impurities (calcite, gypsum, etc.). The F_{mi} was calculated from the difference between the mica curve obtained by quartz adjustment and the new one obtained by subtraction. The F_{mi} values plotted against mica angle were found to lie along the trend established by previous methods.

The final average F_{mi} curve (Figure 7) was only slightly modified from a best fit curve obtained from a composite plot of the above methods. The origin of the curve was shifted slightly from zero to intersect the abscissa at about 2° angular peak breadth. Several plots of F_{mi} values versus mica angle were contoured for mineral percent, using all sample unknowns (approximately 150). Contours for kaolinite, chlorite-vermiculite-montmorillonite, and quartz showed a nearly even distribution of

maxima above and below the F_{mi} curve. Ideally these contour maxima should lie exactly along the curve. A slight change in slope was made on the basis of these distribution contours, yielding the final curve used for this study. It should be emphasized that this curve does not yield equally reliable quantifications of mica for all samples. Adjustments in the reported percent mica have been made for those samples not lying near the curve; that is, for deviations that were greater than 5.0 F_{mi}. It is hoped that continuing studies based on the theoretical model outlined above, will yield more accurate F_{mi} curves, and eventually the desired family of curves.

Mineral Percent Quantification

The procedures previously described (Lapham in O'Neill and others, 1965) for calculating mineral percent were basically followed in this study, but a few additional precautions were taken to achieve greater accuracy. Instrument settings and sample preparation methods were identical in both studies, except for the use of a PICA Blender Mill for more efficient homogenization of the standard samples. A minimum of five good runs per standard mixture and three good runs per unknown sample were made and the mineral component intensities averaged. The number of standard mixtures was increased from 7 to 13 (Table 3) in order to increase the accuracy of the standard mineral percent graphs. The same pure minerals were used in the mixtures, and added by weight percent. A ratio of 3:2 chlorite to vermiculite was retained for the 14Å to 15Å components.

The construction of mineral percent curves follows several steps as described by Lapham in O'Neill and others (op cit.). Using the standard mixtures, the five intensities for each mineral component were averaged and corrected to the arbitrary silicon standard intensity. These were plotted against mineral percent as raw working curves that aided in determining the F_{mi} multiplier for mica (see previous discussion). The intensities were then totaled and recalculated to 100, keeping the same intensity ratios. These recalculated curves are the basic curves for the standard mixture components. The mica curve has been drawn by the use of an additional step in which the F_{mi} multipliers are applied to the raw intensity average of unknown samples before recalculation to 100 intensity units. The final mineral percent curves for unknowns are second derivative curves from the recalculated set. The mineral percent of each component was determined by using all unknown samples and the recalculated curves. These were then retotaled to 85 to 100 percent, depending on the amount of impurities estimated to be present. The total mineral percent to be retotaled generally ranged from about 90 to

115 percent. These retotaled mineral percentages were then plotted against the recalculated intensity (of the recalculated curves), to obtain the final mineral percent curve. Total mineral percentages taken from the derivative curve usually totaled between 91 and 105 percent. These two steps, recalculation and retotaling, take into account variations that result from matrix and orientation effects, as well as the presence of minerals other than the five quantified components. A check on these curves was made using stoichiometric mineral compositions for chlorite-vermiculite-montmorillonite, kaolinite, quartz, and an average feldspar (Table 3). For mica a sliding scale of K_2O was used, ranging from 10 percent for micas with a mica angle less than 10° to 6.0 percent for micas with an angle greater than 60°. The results of the chemical comparison indicated that no change in the mineral percent curves would be advantageous. Deviation was within the limits of expectable deviation from stoichiometric mineral compositions.

Table 3. *Mineral Composition of Standard Mixtures.*
(in weight percent)

Quartz	*Mica*	*Kaolinite*	*Feldspar*	14Å-15Å (C-V-Mo)
80	10	5	5	—
65	25	5	5	—
55	10	20	5	10
50	30	10	10	—
50	50	—	—	—
50	20	5	15	10
40	25	20	10	5
25	40	15	5	15
20	25	40	15	—
15	30	25	10	20
15	20	45	5	15
15	20	30	10	25
15	15	35	5	30

The second derivative curves used in this report (Figure 8), derived from the data on these samples, closely parallel those of the previous report (Lapham, Figure 4 in O'Neill and others, 1965). Maximum mineral percent difference between the two sets of curves is as follows: 10 percent mica, 5 percent quartz, 3 percent feldspar, 2 percent 14Å to 15Å components and 1 percent kaolinite. This is particularly noteworthy since the F_{m1} curve derived in this study has a different slope. Maximum deviations between the two sets of curves lie at the extremes of the earlier set. Here additional standard mixtures have enabled a more accurate extension of the mineral percentages to lower and higher quantities. Small flexure points, which occur at these extremes, are also better defined.

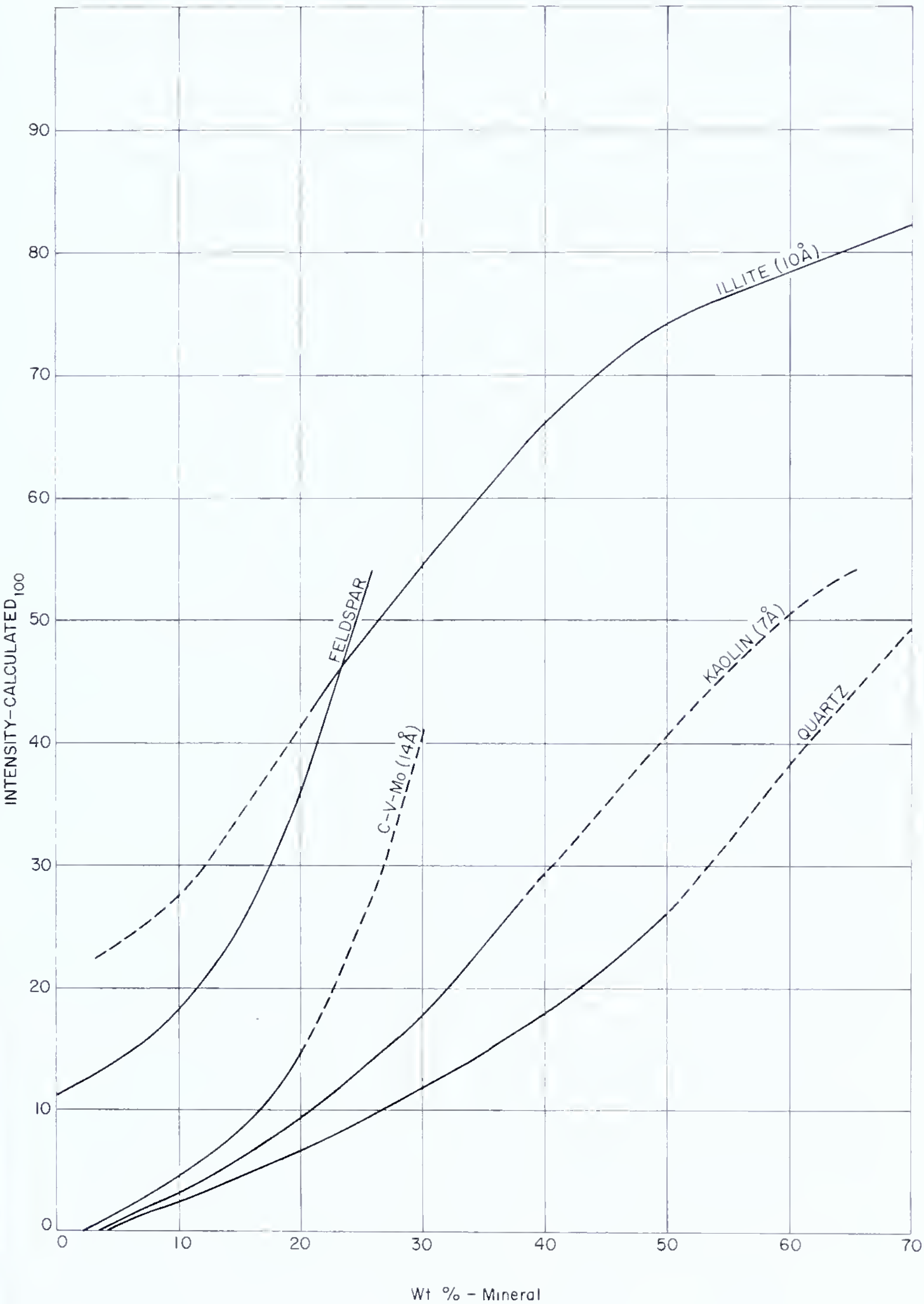


Figure 8. Quantitative mineral X-ray standardization curves.

Accuracy of Mineralogical Analysis

It is not possible to calculate an exact statistical error for each mineral, because the mineral percent curves are second derivative curves computed by a series of calculation steps. However, an estimate can be made based on deviation between mineral percent and the recalculated percent mineral curves (recalculated versus derivative curves). Such estimates are presented in Table 4. The average error (Table 4) for the deviation of about 75 to 80 percent of the samples represents the general accuracy of the method used. In some cases, however, there is considerably greater deviation and this maximum value of error is presented in Table 4. Where the deviation of a sample is significantly greater than the average percent error, this deviation is noted on the Data Sheets for each sample.

The greatest cause of major error occurs when a mica peak is of low intensity and of broad, irregular shape. Here correction for line broadening error is probably high. All the samples are recalculated twice; therefore, an error in any one component can affect the absolute amount of other components. Usually too large a mica angle results (i.e., larger than the area under the curve method would yield) causing the calculated mica intensity to be too high. In such cases, the total of mineral percentages may exceed 100 percent of the total mineral components. Recalculation reduces all components as well as mica. Undoubtedly, another source of error is variation in grain size of the various components in a natural mixture, but this source of error has not been evaluated. Nevertheless, the samples that were re-run from the previous study (O'Neill and others, 1965) and compared in Table 5-A show that these errors are not large, indicating that results obtained by this method are quite consistent. For fine-grained samples (the bulk of the samples in this study) there is no external check method available to calculate absolute deviation.

Table 4. *Mineral Quantification Accuracy (Estimated).*

Mineral Component	*Avg. % Error*	*Maximum % Error*
Kaolinite	±7	10
Mica	±6	18
Quartz	±5	9
Chlorite-Vermiculite-Montmorillonite	±3	6
Feldspar	±2	6

The only available independent check is by chemical calculation from the mineral analysis and subsequent comparison with the chemical analy-

sis (Table 5-B). With the exception of mica, stoichiometric mineral compositions were used to calculate oxide percent. For mica, 8 percent K_2O was used except in sample 157-6-1A where 9 percent K_2O was assumed to be a more correct composition. The deviation of the mineral components from this stoichiometry more than accounts for all ranges in variation shown in Table 5-B. In general the deviations are small, indicating that the mineral quantification is usually an accurate measure of the mineral content of a sample.

Table 5. *Mineral and Chemical—Stoichiometric Comparisons Between This Report and Previous Analyses.*

A. *Mineralogical Comparisons*

Sample No.	*% Chlorite-Vermiculite-Montmorillonite*	*% Mica*	*% Kaolinite*	*% Quartz*	*% Feldspar*
139-6-4					
O'Neill, 1965	10	28	5	35	8
Present Study	14	31	0	42	2
144-5-1					
O'Neill, 1965	1	45	13	33	0
Present Study	7	43	15	26	1
157-6-1A					
O'Neill, 1965	4	43	13	34	1
Present Study	10	32	16	34	2

B. *Chemical-Stoichiometric Mineral Comparisons*

	% SiO	% Al_2O_3	% K_2O
139-6-4			
O'Neill, 1965	59.96	21.84	2.96
Present Study	62.03	14.15	2.66
Chemical Analysis	62.30	18.45	2.40
144-5-1			
O'Neill, 1965	59.70	22.87	3.60
Present Study	55.45	23.20	3.53
Chemical Analysis	60.65	19.70	3.96
157-6-1A			
O'Neill, 1965	61.48	22.64	3.96
Present Study	60.64	20.46	3.06
Chemical Analysis	60.00	19.70	5.00

SAMPLE DATA AND TEST RESULTS

CHEMICAL ANALYSES AND PHYSICAL PROPERTIES

Samples for chemical analysis were prepared from the 100 gram ground samples returned to the Pennsylvania Geological Survey by the U. S. Bureau of Mines. These samples were submitted to a commercial laboratory for quantitative wet chemical analysis, using accepted laboratory methods for silicate rock component determination. Some samples were subject to semi-quantitative spectrographic analysis for trace elements. Four independent commercial laboratories performed the chemical and spectrographic analyses reported upon in this publication.

Data for the chemical analyses are published in the standard manner as reported by the commercial laboratory without recalculation to 100 percent. The analyses consist of quantitative determinations of oxides of the following major elements: silicon, aluminum, trivalent and divalent iron, calcium, magnesium, carbon, sodium, potassium, titantium, phosphorus, and manganese. In addition, organic carbon, water (crystalline and/or adsorbed), and sulfur were determined. Only a few samples were subjected to L. O. I. laboratory analyses.

Chemical analyses and selected physical property data concerning ceramic utilization for the 159 samples of this study are presented in Table 6 (inside back cover), listed by county, quadrangle, sample number and formation. Correlation of potential use with mineralogy, rock type, and chemical analysis is presented in "Evaluation of Analytical Data".

INDIVIDUAL SAMPLE DATA

Information is presented for each sample by county (see data sheets and Table 6). Figure 2 is a geologic map of southeastern Pennsylvania upon which the approximate location for each sample collecting site has been plotted.

Caution must be exercised in comparing laboratory data for samples of the same stratigraphic unit. The samples generally were not collected with any stratigraphic control so that one sample of the Martinsburg Formation, for example, may be stratigraphically higher or lower in the section than another; or it may be from a slightly different lithofacies. The various parameters therefore should be used only in a general way when correlating between samples, although such correlations may yield data trends. The validity of the laboratory data for a given sample is limited to the immediate sampling site area and these limitations must be kept in mind when the data is reviewed for a commercial operation at that particular site.

Some of the abbreviated terms used on the data sheets are defined as follows:

C-V-Mo: Chlorite, vermiculite, and montmorillonite undifferentiated.

L.O.I.: Loss-on-ignition. For samples on which loss-on-ignition was not determined, this value may be approximated by adding per cent CO_2, organic carbon, combined water, and sulfur.

N.D.: Not Determined

N.A.: Not Analyzed

% Abs.: Percent of Absorption

% Shk.: Percent Drying Shrinkage

ADAMS COUNTY Menallen Twp.

Sample Number
128-9-2

Quadrangle: Newville 15′; Dickinson 7½′

Location: Quarry about 2.5 miles northwest of Bendersville, Pa. (40°00′05″ North Latitude; 77°17′00″ West Longitude).

Geologic Unit: Sericite Schist, Precambrian

Description: A predominantly greenish-gray to pale red-purple schist is exposed in the quarry. The schist is heavily slickensided, and contains abundant white and rose quartz veins. The quarry is 200 feet by 150 feet and is 40 feet deep.

Attitude of Bedding: Obscured; Shistosity: N45°E, S

Sampled Interval: Grab sample of greenish gray schist.

Type of Material: Sericite Schist

Ceramic Testing Laboratory: Tuscaloosa

Chemical Analysis:

Analyst: McCreath	%
L.O.I. @ 1,000°C	1.77
H_2O Loss @ 110°C	NA
Combined H_2O	NA
SiO_2	72.42
Al_2O_3	13.03
Fe_2O_3	3.53
FeO	0.89
CaO	NA
MgO	0.64
CO_2	0.32
Na_2O	1.31
K_2O	5.04
TiO_2	0.37
P_2O_5	NA
MnO	NA
S (total)	NA
C (total)	NA

Mineralogy (X-ray):

	%	Accuracy (±%)
Quartz	43	8
Mica	46	10
Kaolinite	8	6
C-V-Mo	0	
Feldspar	2	1
Remarks:		

Other Properties:

pH: 5.80
P.C.E.: NA
Water of Plasticity (%): 14.8
Drying Shrinkage (%): 0.0
Dry Strength: Low
Drying Characteristics: Satisfactory
Workability: Smooth; non-plastic

Slow-Firing Tests:

Temp. °F	Color	Hardness	% Shk.	% Absorb.	% App. Por.	Approx. Sp. Gr.
1800	No bond	—	—	—	—	—
1900	Light tan	Moh's 2	0.0	21.6	—	1.59
2000	Tan	Moh's 2	0.0	18.6	—	1.67
2100	Buff	Moh's 5	0.0	13.8	—	1.82
2200	Brown	Moh's 6	7.5	5.9	—	2.13
2300	Melted					

Pyrometric cone equivalent: NA **Bloating test:** Negative

Remarks: Very short working; poor color; narrow firing range.

Bloating Tests (Quick Firing): NA

Other Tests: Thin Section Study: 35% sericite; 65% quartzo—feldspathic minerals. Color of powder: white to light greenish gray.

Potential Uses: No designated ceramic use.

Remarks: Sampled material is thought to be used as a "Filler".

ADAMS COUNTY Menallen Twp.

Sample Number
129-2-6

Quadrangle: Fairfield 15′; Arendtsville 7½′

Location: Exposure in drainage ditch of road, about 3 miles northwest of Bridgeport, Pa. (39°51′30″ North Latitude; 77°21′3″ West Longitude).

Geologic Unit: Sericite Schist, Precambrian

Description: Grayish-red purple to very dark-red sericite schist is exposed in a drainage ditch and roadbank on the northeast side of the road. Metarhyolite borders the schist on both sides.

Attitude of Bedding: Obscured. Schistosity: N30-40E, S

Sampled Interval: Composite sample across the entire 45 feet of exposure.

Type of Material: Sericite Schist

Ceramic Testing Laboratory: Tuscaloosa

Chemical Analysis:

Analyst: McCreath	%
L.O.I. @ 1,000°C	4.20
H_2O Loss @ 110°C	NA
Combined H_2O	NA
SiO_2	41.40
Al_2O_3	28.35
Fe_2O_3	13.29
FeO	0.23
CaO	NA
MgO	0.21

Mineralogy (X-ray):

	%	Accuracy (±%)
Quartz	20	10
Mica	73	12
Kaolinite	0	—
C-V-Mo	0	—
Feldspar	2	2

Remarks: Data unreliable. Contains amorphous Fe^3 hydroxide.

Chemical Analysis:

Analyst: McCreath	%
CO_2	0.05
Na_2O	0.17
K_2O	9.78
TiO_2	0.50
P_2O_5	NA
MnO	NA
S (total)	NA
C (total)	NA

Other Properties:

pH: 6.00
P.C.E.: NA
Water of Plasticity (%): 13.5
Drying Shrinkage (%): 0.0
Dry Strength: Low
Drying Characteristics: Satisfactory
Workability: Gritty; non-plastic

Slow-Firing Tests:

Temp. °F	*Color*	*Hardness*	*% Shk.*	*% Absorb.*	*% App. Por.*	*Approx. Sp. Gr.*
1800	No bond	—	—	—	—	—
1900	Sand	Moh's 2	0.0	17.2	—	1.80
2000	Light buff	Moh's 4	0.0	17.1	—	1.83
2100	Buff	Moh's 4	0.0	13.2	—	1.96
2200	Brown	Moh's 7	2.5	5.5	—	2.26
2300	Brown	Moh's 7+	5.0	1.6	—	2.27

Pyrometric cone equivalent: NA **Bloating test:** Negative

Remarks: Very short working; poor color.

Bloating Tests (Quick-Firing): NA

Other Tests: Thin Section Study: 90% sericite; 10% quartzo—feldspathic minerals.

Potential Uses: No designated ceramic use.

ADAMS COUNTY Menallen Twp.

Sample Number
129-3-7

Quadrangle: Fairfield 15′; Arendtsville 7½′

Location: Exposure along the Bendersville-Wenksville road about 1.8 miles northwest of Bendersville, Pa. where road changes direction from NW-SE to SW-NE. The outcrop is along the northwest side of the macadam road which parallels Opossum Run.

Geologic Unit: Sericite Schist, Precambrian

Description: Light-greenish gray to greenish gray sericite schist is exposed in the roadcut and is extensively folded and slickensided.

Attitude of Bedding: Obscured; Schistosity: N35E, S

Sampled Interval: Channel sample across schistosity of entire exposure.

Type of Material: Sericite Schist

Ceramic Testing Laboratory: Tuscaloosa

Chemical Analysis:

Analyst: McCreath	%
L.O.I. @ 1,000°C	1.20
H_2O Loss @ 110°C	NA
Combined H_2O	NA
SiO_2	83.77
Al_2O_3	8.51
Fe_2O_3	2.10
FeO	0.43
CaO	NA
MgO	0.11
CO_2	0.05
Na_2O	0.04
K_2O	3.24
TiO_2	0.10
P_2O_5	NA
MnO	NA
S (total)	NA
C (total)	NA

Mineralogy (X-ray):

	%	Accuracy (±%)
Quartz	58	10
Mica	35	10
Kaolinite	0	—
C-V-Mo	0	—
Feldspar	2	2

Remarks: Mineralogy indicates chemical analysis is high in SiO_2 and low in Al_2O_3. Data are uncertain.

Other Properties:

pH: 5.50
P.C.E.: NA
Water of Plasticity (%): 18.0
Drying Shrinkage (%): 0.0
Dry Strength: Low
Drying Characteristics: Satisfactory
Workability: Gritty, low plasticity

Slow-Firing Tests:

Temp. °F	*Color*	*Hardness*	*% Shk.*	*% Absorb.*	*% App. Por.*	*Approx. Sp. Gr.*[1]
1800	No bond	—	—	—	—	—
1900	No bond	—	—	—	—	—
2000	Light buff	Moh's 2	0.0	22.3	—	1.66
2100	Buff	Moh's 3	0.0	18.7	—	1.79
2200	Light brown	Moh's 4	2.5	14.5	—	1.88
2300	Brown	Moh's 7	2.5	9.7	—	2.04

[1] Bulk Density—gm/cc

Pyrometric cone equivalent: Na **Bloating test:** Negative

Remarks: Short working; very low green strength.

Bloating Tests (Quick-Firing): NA

Other Tests: Thin Section Study: 20% sericite; 80% quartzo—feldspathic minerals. Color of powder: white to light greenish gray.

Potential Uses: No designated ceramic use.

ADAMS COUNTY Menallen Twp.

Sample Number
129-3-8

Quadrangle: Fairfield 15′; Arendtsville 7½′

Location: Discontinuous outcrops of schist along the northwest side of a macadam road about 0.3 mile southwest of Kensville, Pa.

Geologic Unit: Sericite Schist, Precambrian

Description: Light-greenish gray to greenish-gray sericite schist with vein quartz intermittently crops out for a distance of about 0.2 mile along the side of the road. The schist is bounded on both sides by metarhyolite.

Attitude of Bedding: Obscured

Sampled Interval: Composite sample of a 25 foot exposure in a drainage ditch.

Type of Material: Sericite Schist

Ceramic Testing Laboratory: Tuscaloosa

Chemical Analysis:

Analyst: McCreath	%
L.O.I. @ 1,000°C	2.15
H_2O Loss @ 110°C	NA
Combined H_2O	NA
SiO_2	75.28
Al_2O_3	11.15
Fe_2O_3	4.17
FeO	0.35
CaO	NA
MgO	0.59
CO_2	$<$ 0.01
Na_2O	0.11
K_2O	5.27
TiO_2	0.31
P_2O_5	NA
MnO	NA
S (total)	NA
C (total)	NA

Mineralogy (X-ray):

	%	Accuracy (±%)
Quartz	5	10
Mica	90	25
Kaolinite	0	—
C-V-Mo	0	—
Feldspar	2	2

Remarks: Mineralogy indicates chemical analysis is high in SiO_2 and low in Al_2O_3. Data are uncertain; see "Other Tests".

Other Properties:

pH: 5.70
P.C.E.: NA
Water of Plasticity (%): 18.8
Drying Shrinkage (%): 0.0
Dry Strength: Low
Drying Characteristics: Satisfactory
Workability: Gritty; low-plasticity

Slow-Firing Tests:

Temp. °F	*Color*	*Hardness*	*% Shk.*	*% Absorb.*	*% App. Por.*	*Approx. Sp. Gr.*
1800	No bond	—	—	—	—	—
1900	Light tan	Moh's 2	0.0	25.5	—	1.60
2000	Tan	Moh's 2+	0.0	21.2	—	1.69
2100	Dark tan	Moh's 4	2.5	13.4	—	1.94
2200	Brown	Moh's 6	10.0	4.3	—	2.36
2300	Brown	Moh's 7+	10.0	1.6	—	2.36

Pyrometric cone equivalent: NA **Bloating test:** Negative

Remarks: Short working; low green strength; color marginal.

Bloating Tests (Quick-Firing): NA

Other Tests: Thin Section Study: 50% sericite; 50% quartzo—feldspathic minerals. Color of powder: white to light greenish gray.

Potential Uses: No designated ceramic use; may have use as a filler material (see remarks below).

Remarks: Study of sericite schist deposits of Adams County by Richard Weiss (unpublished Pennsylvania Geological Survey Open File Report) indicates that the sericite schist from this location has potential for use as a filler material, based on its mineralogical and powder color characteristics which are similar to the Summit Mining operation.

ADAMS COUNTY Hamiltonban Twp.

Sample Number
129-7-3

Quadrangle: Fairfield 15′; Iron Springs 7½′

Location: Quarry on west bank of unnamed stream about 1000 feet north of the school and cemetery in Mt. Hope, Pa.

Geologic Unit: Sericite schist, Precambrian

Description: A predominantly light-greenish gray sericite schist occurs at the contact between metarhyolite and metabasalt.

Attitude of Bedding:

Sampled Interval: Grab sample from a muck pile in the quarry.

Type of Material: Sericite schist

Ceramic Testing Laboratory: Tuscaloosa

Chemical Analysis:

Analyst: McCreath	%
L.O.I. @ 1,000°C	1.72
H_2O Loss @ 110°C	NA
Combined H_2O	NA
SiO_2	74.13
Al_2O_3	11.80
Fe_2O_3	2.77
FeO	1.24
CaO	NA
MgO	1.65
CO_2	0.40
Na_2O	0.89
K_2O	4.67
TiO_2	0.38
P_2O_5	NA
MnO	NA
S (total)	NA
C (total)	NA

Mineralogy (X-ray):

	%	Accuracy (±%)
Quartz	52	7
Mica	41	8
Kaolinite	0	—
C-V-Mo	0	—
Feldspar	2	1

Remarks:

Other Properties:

pH: 5.70
P.C.E.: NA
Water of Plasticity (%): 18.8
Drying Shrinkage (%): 0.0
Dry Strength: Low
Drying Characteristics: Satisfactory
Workability: Gritty, low plasticity

Slow-Firing Tests:

Temp. °F	*Color*	*Hardness*	*% Shk.*	*% Absorb.*	*% App. Por.*	*Approx. Sp. Gr.*
1800	No bond	—	—	—	—	—
1900	Lt. buff	Moh's 2	0.0	18.9	—	1.70
2000	Lt. buff	Moh's 4	0.0	13.8	—	1.86
2100	Lt. brown	Moh's 7	5.0	7.4	—	2.08
2200	Gray-green	Moh's 7+	5.0	0.0	—	2.08
2300	Overfired					

Pyrometric cone equivalent: NA **Bloating test:** Negative

Remarks: Short working; low green strength; poor color.

Bloating Tests (Quick-Firing): NA

Other Tests: Thin Section Study: 40% sericite; 60% quartzo—feldspathic minerals. Color of powder: white to very light gray.

Potential Uses: No designated ceramic use.

Remarks: The quarry is presently being operated to make filler materials.

ADAMS COUNTY Hamiltonban Twp.

Sample Number
129-7-4

Quadrangle: Fairfield 15′; Iron Springs 7½′

Location: Intermittent outcrops along slope on north side of road between Gladhill and Maria Furnace, Pa., about 1.5 miles northeast of Gladhill, Pa.

Geologic Unit: Sericite schist, Precambrian

Description: Light-greenish gray to greenish gray, slightly to moderately weathered sericite schist crops out at the metarhyolite-metabasalt contact. Drag folds in the schist indicate the crest of an anticlinal structure lies to the east. Slickensided surfaces are common and white quartz is disseminated throughout the schist. About 25 feet of schist are exposed.

Attitude of Bedding: Obscured; Schistosity: N15E, 75S

Sampled Interval: Composite sample collected across 15 feet of the outcrop.

Type of Material: Sericite schist

Ceramic Testing Laboratory: Tuscaloosa

Chemical Analysis:

Analyst: McCreath	%
L.O.I. @ 1,000°C	1.65
H_2O Loss @ 110°C	NA
Combined H_2O	NA
SiO_2	75.42
Al_2O_3	11.63
Fe_2O_3	2.80
FeO	0.98
CaO	NA
MgO	1.19
CO_2	0.14
Na_2O	0.90
K_2O	4.27
TiO_2	0.35
P_2O_5	NA
MnO	NA
S (total)	NA
C (total)	NA

Mineralogy (X-ray):

	%	*Accuracy (±%)*
Quartz	53	6
Mica	38	7
Kaolinite	0	—
C-V-Mo	0	—
Feldspar	4	2

Remarks:

Other Properties:

pH: 6.50
P.C.E.: NA
Water of Plasticity (%): 18.6
Drying Shrinkage (%): 0.0
Dry Strength: Low
Drying Characteristics: Satisfactory
Workability: Gritty; low plasticity

Slow-Firing Tests:

Temp. °F	Color	Hardness	% Shk.	% Absorb.	% App. Por.	Approx. Sp. Gr.
1800	No bond	—	—	—	—	—
1900	Lt. buff	Moh's 2	0.0	21.5	—	1.62
2000	Lt. buff	Moh's 4	0.0	17.2	—	1.76
2100	Lt. brown	Moh's 7	2.5	9.8	—	2.00
2200	Gray-green	Moh's 7+	7.5	1.5	—	2.22
2300	Overfired					

Pyrometric cone equivalent: NA **Bloating test:** Negative

Remarks: Short working; low green strength; poor color.

Bloating Tests (Quick-Firing): NA

Other Tests: Thin Section Study: 35% sericite; 65% quartzo—feldspathic minerals. Color of powder: white to light greenish gray.

Potential Uses: No designated ceramic use.

Remarks: See Remarks for Sample 129-3-8

ADAMS COUNTY Hamiltonban Twp.

Sample Number
129-7-5

Quadrangle: Fairfield 15′; Iron Springs 7½′

Location: Summit Industries, Incorporated, Mt. Hope Quarry, about 0.35 mile east of the Mt. Hope School.

Geologic Unit: Sericite schist, Precambrian

Description: Sericite schist in the quarry ranges from olive gray to greenish gray, dark greenish gray and pale red purple. The pale red purple sericite schist which is limited to the eastern portion of the quarry, was collected to determine whether it differed from the greenish gray variety in test results and potential use. The quarry measures about 150 feet in length, 80 feet in width, and is 80 feet high.

Sampled Interval: Grab sample of pale red purple sericite schist.

Type of Material: Sericite schist

Ceramic Testing Laboratory: Tuscaloosa

Chemical Analysis:

Analyst: Conwell	%
L.O.I. @ 1,000°C	2.74
H_2O Loss @ 110°C	0.26
Combined H_2O	2.04
SiO_2	67.08
Al_2O_3	17.13
Fe_2O_3	5.35
FeO	0.07
CaO	0.30
MgO	1.79
CO_2	0.06

Mineralogy (X-ray):

	%	Accuracy (±%)
Quartz	47	5
Mica	46	6
Kaolinite	0	—
C-V-Mo	0	—
Feldspar	2	1
Remarks:		

Chemical Analysis:

Analyst: Conwell

	%
Na_2O	0.03
K_2O	4.65
TiO_2	0.32
P_2O_5	NA
MnO	NA
S (total)	None
C (total)	0.11

Other Properties:

pH: 6.70
P.C.E.: NA
Water of Plasticity (%): 18.8
Drying Shrinkage (%): 0.0
Dry Strength: Low
Drying Characteristics: Satisfactory
Workability: Gritty; low plasticity

Slow-Firing Tests:

Temp. °F	*Color*	*Hardness*	*% Shk.*	*% Absorb.*	*% App. Por.*	*Approx. Sp. Gr.*
1800	No bond	—	—	—	—	—
1900	Lt. buff	Moh's 3	0.0	19.4	—	1.70
2000	Buff	Moh's 4	5.0	12.0	—	1.97
2100	Lt. brown	Moh's 7	5.0	5.6	—	2.20
2200	Gray-green	Moh's 7+	5.0	0.7	—	1.98
2300	Overfired					

Pyrometric cone equivalent: NA **Bloating test:** Negative

Remarks: Short working; low green strength; poor color.

Bloating Tests (Quick-Firing): NA

Other Tests: None

Potential Uses: No designated ceramic use.

Remarks: See Remarks for Sample 129-3-8

ADAMS COUNTY Huntington Twp.

Sample Number
138-7-3A

Quadrangle: Carlisle 15′; Mt. Holly Springs 7½′

Location: Quarry on the Pape Farm about 0.4 mile northeast of Gargol, Pa., on the west side of the macadam road trending northeast from the town of Gargol.

Geologic Unit: Pyrophyllite Deposit, Precambrian

Description: White (N9) to very-light gray (N8), residue clay developed from weathering of the underlying pyrophyllite. Locally there are patches of dark-yellow to orange (10 YR 6/6) clay associated with plant roots.

Sampled Interval: Channel sample taken 5 feet vertically through the deposit.

Type of Material: Clay, residue, pyrophyllite

Ceramic Testing Laboratory: Norris

Chemical Analysis:

Analyst: Spectrochemical %

L.O.I. @ 1,000°C	5.01
H_2O Loss @ 110°C	0.55
Combined H_2O	NA
SiO_2	77.00
Al_2O_3	12.00
Fe_2O_3	2.49
FeO	0.01
CaO	< 0.05
MgO	0.30
CO_2	0.11
Na_2O	0.85
K_2O	1.90
TiO_2	0.24
P_2O_5	NA
MnO	NA
S (total)	0.02
C (total)	0.09

Mineralogy (X-ray):

	%	Accuracy (±%)
Quartz		
Mica		
Kaolinite		
C-V-Mo		
Feldspar		

Remarks: High pyrophyllite; quartz > mica < kaolin; trace of feldspar.

Other Properties:

pH: 5.80
P.C.E.: NA
Water of Plasticity (%): 34.6
Drying Shrinkage (%): 0.0
Dry Strength: Fair
Drying Characteristics: Fair; warping
Workability: Gritty; smooth; short-working

Slow-Firing Tests:

Temp. °F	*Color*	*Hardness*	*% Shk.*	*% Absorb.*	*% App. Por.*	*Approx. Sp. Gr.*
1800	Buff	Crumbled in water				
1900	Buff	Soft	0.0	2.9	—	2.35
2000	Buff	Soft	0.0	3.0	—	2.33
2100	Buff	Soft	0.0	3.0	—	2.30
2200	Buff	Fair hard	4.0	36.0	—	2.33
2300	Light gray	Hard	5.0	42.4	—	2.38

Pyrometric cone equivalent: NA **Bloating test:** Negative

Remarks: Too soft; high silica content.

Bloating Tests (Quick-Firing): NA

Other Tests: Soluble Br. K. 0.65

Potential Uses: No designated ceramic use; insecticide filler.

Remarks: The clay is presently being extracted and used as a filler for insecticides.

ADAMS COUNTY Huntington Twp.

Sample Number
138-7-3B

Quadrangle: Carlisle 15′; Mt. Holly Springs 7½′

Location: Quarry on the Pape Farm about 0.4 mile northeast of Gargol, Pa., on the west side of the macadam road trending northeast from the town of Gargol.

Geologic Unit: Pyrophyllite, Precambrian

Description: Light-greenish gray (GY 8/1) to greenish gray (5 G 6/1) schistose pyrophyllite crops out at places in the quarry. The pyrophyllite occurs as en echelon lenses within greenstone. Diamond core drilling in the late 1940's indicated that the pyrophyllite occurs

in a series of pod-like lenses, each extending 100 to 200 feet along the strike with a maximum thickness of less than 25 feet. The lenses apparently pinch-out down dip. The rock in the quarry is highly distorted.

Attitude of Bedding: Obscured. Schistosity N25-60E, 60E

Sampled Interval: Composite sample of 25 feet of stratigraphic section.

Type of Material: Pyrophyllite

Ceramic Testing Laboratory: Norris

Chemical Analysis:

Analyst: Spectrochemical %

L.O.I. @ 1,000°C	4.85
H_2O Loss @ 110°C	0.15
Combined H_2O	NA
SiO_2	51.50
Al_2O_3	34.70
Fe_2O_3	1.19
FeO	0.05
CaO	0.11
MgO	0.22
CO_2	0.07
Na_2O	1.73
K_2O	4.80
TiO_2	0.81
P_2O_5	NA
MnO	NA
S (total)	0.04
C (total)	0.14

Mineralogy (X-ray):

	%	*Accuracy (±%)*
Quartz		
Mica		
Kaolinite		
C-V-Mo		
Feldspar		

Remarks: High pyrophyllite; mica > quartz; trace of feldspar.

Other Properties:

pH: 7.45
P.C.E.: NA
Water of Plasticity (%): 47.6
Drying Shrinkage (%): 0.0
Dry Strength: Good
Drying Characteristics: Fair; warping
Workability: Plastic; smooth; long-working

Slow-Firing Tests:

Temp. °F	*Color*	*Hardness*	*% Shk.*	*% Absorb.*	*% App. Por.*	*Approx. Sp. Gr.*
1800	Pale pink	Soft	0.0	2.7	—	2.20
1900	Pale pink	Soft	1.0	2.9	—	2.42
2000	Pale pink	Fair hard	5.0	2.6	—	2.52
2100	Off white	Fair hard	4.0	3.4	—	2.20
2200	Off white	Hard	5.5	4.8	—	2.24
2300	Light gray	Very hard	9.5	10.5	—	2.16

Pyrometric cone equivalent: NA **Bloating test:** Negative

Remarks: Red specks, considerable warping, rather soft below 2200°F. Washing would improve properties.

Bloating Tests (Quick-Firing): NA

Other Tests: Soluble Br. K. 2.00

Potential Uses: No designated ceramic use. Additive to improve properties of other clays; insecticide filler.

Remarks: Summit Mining Corporation is presently extracting the material for use as a filler in insecticides.

ADAMS COUNTY Huntington Twp.

Sample Number
138-7-5

Quadrangle: Carlisle 15′; Mt. Holly Springs 7½′

Location: Road exposure about 0.7 mile southeast of Peach Glen, Pa., along northeast side of road between Peach Glen and Idaville, Pa.

Geologic Unit: Sericite schist, Precambrian

Description: Light greenish-gray to greenish-gray sericite schist is exposed in the road cut for a distance of about 25 feet. White quartz is also present. The exposure is about 5 feet high.

Attitude of Bedding: Obscured

Sampled Interval: Channel sample (across schistosity) for a distance of 10 feet.

Type of Material: Sericite schist

Ceramic Testing Laboratory: Tuscaloosa

Chemical Analysis:

Analyst: McCreath	%
L.O.I. @ 1,000°C	NA
H_2O Loss @ 110°C	NA
Combined H_2O	NA
SiO_2	80.76
Al_2O_3	9.00
Fe_2O_3	2.46
FeO	1.64
CaO	NA
MgO	< 0.50
CO_2	0.01
Na_2O	0.07
K_2O	3.71
TiO_2	0.14
P_2O_5	NA
MnO	NA
S (total)	NA
C (total)	NA

Mineralogy (X-ray):

	%	Accuracy (±%)
Quartz	56	12
Mica	36	14
Kaolinite	0	—
C-V-Mo	0	—
Feldspar	2	1

Remarks: Mineralogy indicates chemical analysis is high in SiO_2 and low in Al_2O_3. Data are uncertain.

Other Properties:

pH: 580
P.C.E.: NA
Water of Plasticity (%): 14.0
Drying Shrinkage (%): 0.0
Dry Strength: Low
Drying Characteristics: Satisfactory
Workability: Gritty; non-plastic

Slow-Firing Tests:

Temp. °F	*Color*	*Hardness*	*% Shk.*	*% Absorb.*	*% App. Por.*	*Approx. Sp. Gr.*
1800	No bond	—	—	—	—	
1900	No bond	—	—	—	—	
2000	Buff	3	0.0	16.9	—	1.78
2100	Buff	4	0.0	10.7	—	1.91
2200	Brown	7	2.5	7.6	—	2.04
2300	Melted					

Pyrometric cone equivalent: NA **Bloating test:** Negative

Remarks: Very short working; narrow firing range; poor color.

Bloating Tests (Quick-Firing): NA

Other Tests: Thin Section Study: 20% sericite; 80% quartzo—feldspathic minerals. Color of powder: white to light greenish gray.

Potential Uses: No designated ceramic use.

ADAMS COUNTY Butler Twp.

Sample Number
139-1-5A

Quadrangle: Gettysburg 15′; Biglerville 7½′

Location: Road exposure about 1.5 miles southeast of Biglerville, Pa., or about 0.5 mile northwest of Table Rock, Pa., along the east side of a paved road. (U.S.G.S. 7½ quadrangle map, 1944 shows this as an unimproved road).

Geologic Unit: Heidlersburg Member, Gettysburg Formation, Triassic.

Description: Five samples of slightly different lithologies were collected at this exposure to determine whether these compositional differences would be reflected in use potential trends. The oldest beds sampled occur in the southern part of the exposure and are designated as Sample A (139-1-5A). This sample represents a stratigraphic thickness of 5 feet and consists of a thin (5 inch) basal siliceous argillite overlain by 3-to-7-inch thick beds of grayish-red (5 R 4/2) argillite. The beds are calcareous and contain a small amount of visible mica. Samples of the younger rocks were collected as samples B through E (139-1-5B to E).

Attitude of Bedding: N50E, 20N

Sampled Interval: Composite sample of unit.

Type of Material: Argillite

Ceramic Testing Laboratory: Norris

Chemical Analysis:

Analyst: McCreath

	%
L.O.I. @ 1,000°C	NA
H_2O Loss @ 110°C	NA
Combined H_2O	3.08
SiO_2	50.05
Al_2O_3	17.70
Fe_2O_3	4.95
FeO	1.07
CaO	5.65
MgO	2.75
CO_2	5.49
Na_2O	3.76
K_2O	2.75
TiO_2	0.86
P_2O_5	NA
MnO	NA
S (total)	> 0.09
C (total)	0.09

Mineralogy (X-ray):

	%	*Accuracy* ($\pm$%)
Quartz	12	5
Mica	41	6
Kaolinite	10	6
C-V-Mo	8	3
Feldspar	19	3

Remarks: Carbonates present

Other Properties:

pH: 9.35
P.C.E.: NA
Water of Plasticity (%): 23.6
Drying Shrinkage (%): 4.5
Dry Strength: Good
Drying Characteristics: Fair, warping, slight scum
Workability: Short, fairly smooth, fatty

Slow-Firing Tests:

Temp. °F	*Color*	*Hardness*	*% Shk.*	*% Absorb.*	*% App. Por.*	*Approx. Sp. Gr.*
1800	Light brown	Fair hard	5.0	4.3	—	2.61
1900	Light brown	Fair hard	5.0	4.6	—	2.63
2000	Light brown	Hard	5.0	7.1	—	2.54
2100	Melted					
2200						
2300						

Pyrometric cone equivalent: NA **Bloating test:** Positive

Remarks: Poor color, dull, soft, melts below 2100°F., slight expansion at 2050°F.

Bloating Tests (Quick-Firing):

Crushing characteristics: Good Particle size: —¾" + ½"
Drying characteristics: Good Retention time: 15 minutes

Temp. °F	*Bulk Density*	*Lb/Ft³*	*% Absorb.*	*Remarks*
1800	—	—	—	
1900	2.55	159	2.0	No expansion
2000	1.24	79	1.4	Fair expansion
2100	0.95	60	2.7	Very good expansion
2200				Melted
2300				

Recommendations: Very good lightweight aggregate possibility.

ROTARY KILN TESTS:

Raw Material:

Screen Analysis (Crushed through a hammermill with 1½" screen)

Size		*Percent Retained*
—¾"	+ ½"	29.4
—½"	+ ⅜"	16.9
—⅜"	+ 4 mesh	23.9
—4 mesh	+ 8 mesh	6.3
—8 mesh	PAN	23.5
	TOTAL	100.0

Crushing loss (—4 mesh) 29.8%

Fragment shape: Angular

Firing Data:

Size range of feed: —¾ + 4 mesh Pour weight of feed: 82.0 lb/ft³
Bloating temperature: 2020°F
Logging temperature* (*Nodules sticking together): 2060°F

Fired Material (all fired material crushed through a roll crusher)

Screen Analysis* (*ASTM Designation C 311-59T) in percentages by weight passing sieves:

Size designation	¾″	½″	⅜″	No. 4	No. 8	No. 16	No. 50	No. 100
Fine	—	—	100.0	63.0	—	23.0	8.5	5.5
Coarse	100.0	73.0	43.0	5.0	1.6	—	—	—

Loose pour weight* (*ASTM Designation C 311-59T):
Fine: 70.0 lb/ft^3 Coarse: 62.5 lb/ft^3

COMMENTS: Not promising for lightweight aggregate. Tabular fragments; mostly nonbloating material. NOTE. This sample is composite of Samples 139-1-5A, B, and C.

Other Tests: Soluble Br. K. 1.30

Potential Uses: No designated ceramic use. Samples 139-1-5A, B, and C were collected as one bulk sample for rotary kiln testing, the results of which indicated this material was not promising for production of lightweight aggregate. Quick-firing tests suggest Sample 139-1-5A has very good lightweight aggregate potential but most likely the 5 feet of stratigraphic thickness is too thin for a commercial operation especially with addition of overlying units as overburden.

Remarks: Samples 139-1-5A, 139-1-5B, and 139-1-5C collected as one sample for rotary kiln tests.

ADAMS COUNTY Butler Twp.

Sample Number
139-1-5B

Quadrangle: Gettysburg 15′; Biglerville 7½′

Location: Road exposure about 1.5 miles southeast of Biglerville or about 0.5 mile northwest of Table Rock, Pa., along east side of paved road. (U.S.G.S. 7½′ quadrangle map 1944).

Geologic Unit: Heidlersburg Member, Gettysburg Formation, Triassic.

Description: Five samples of slightly different lithologies were collected at this exposure to determine whether these compositional differences would be reflected in use potential trends. The oldest beds sampled occur in the southern part of the exposure and are designated as Sample A (139-1-5A). Samples of younger rocks were collected as Sample B through E (139-1-5B though E). Sample B represents 2 feet of calcareous, medium gray to green gray, fissile shale overlying Sample A. The shale contains a minor amount of pyrite and plant fossils are present in the lower beds of the unit.

Attitude of Bedding: N50E, 20N

Sampled Interval: Composite of entire unit.

Type of Material: Shale

Ceramic Testing Laboratory: Norris

Chemical Analysis:

Analyst: McCreath	%
L.O.I. @ 1,000°C	NA
H_2O Loss @ 110°C	NA

Mineralogy (X-ray):

	%	Accuracy (±%)
Quartz	14	7
Mica	54	6

Chemical Analysis:

Analyst: McCreath

	%
Combined H_2O	4.24
SiO_2	48.18
Al_2O_3	17.70
Fe_2O_3	5.89
FeO	1.44
CaO	4.46
MgO	3.51
CO_2	4.36
Na_2O	3.24
K_2O	3.73
TiO_2	0.90
P_2O_5	NA
MnO	NA
S (total)	$>$ 0.54
C (total)	0.10

Mineralogy (X-ray):

	%	Accuracy (±%)
Kaolinite	11	5
C-V-Mo	8	3
Feldspar	9	2

Remarks:

Other Properties:

pH: 9.25
P.C.E.: NA
Water of Plasticity (%): 23.0
Drying Shrinkage (%): 5.0
Dry Strength: Good
Drying Characteristics: Fair, slight warping checking
Workability: Short working, smooth, fatty

Slow-Firing Tests:

Temp. °F	*Color*	*Hardness*	*% Shk.*	*% Absorb.*	*% App. Por.*	*Approx. Sp. Gr.*
1800	Tan	Fair hard	5.5	4.4	—	2.63
1900	Tan	Fair hard	5.5	4.2	—	2.60
2000	Light brown	Hard	6.0	5.0	—	2.53
2100	Melted					
2200						
2300						

Pyrometric cone equivalent: NA **Bloating test:** Positive

Remarks: Poor color, dull, soft, melts below 2100°F., bloating at 2050°F.

Bloating Tests (Quick-Firing):

Crushing characteristics: Good Particle size: —¾″ + ½″
Drying characteristics. Good Retention time: 15 minutes

Temp. °F	*Bulk Density*	*Lb/Ft³*	*% Absorb.*	*Remarks*
1800	—	—	—	
1900	2.56	160	2.0	No expansion
2000	0.94	59	1.4	Fine expansion
2100	1.06	66	2.7	Very good expansion—some fusion
2200				Melted
2300				

Recommendations: Very good lightweight aggregate possibility; short bloating range.

Other Tests: Soluble Br. K. 1.00

Potential Uses: No designated ceramic use. Rotary kiln tests (See Sample 139-1-5A) indicated that this material is not promising as raw material for lighweight aggregate use. Quick-firing tests suggest Sample 139-1-5B has potential for use as lightweight aggregate. However, the unit is too thin for a commercial operation.

Remarks: Samples 139-1-5A, 139-1-5B, and 139-1-5C collected as one sample for rotary kiln tests. See rotary kiln data for Sample 139-1-5A for results of these tests.

ADAMS COUNTY Butler Twp.

Sample Number
139-1-5C

Quadrangle: Gettysburg 15′; Biglerville 7½′

Location: Road exposure about 1.5 miles southeast of Biglerville or about 0.5 mile northwest of Table Rock, Pa., along the east side of a paved road (1944 edition of Biglerville 7½′ Quadrangle shows this as an unimproved road).

Geologic Unit: Heidlersburg Member, Gettysburg Formation, Triassic.

Description: Five samples of slightly different lithologies were collected at this exposure to determine whether these compositional differences would be reflected in use potential trends. The oldest beds sampled occur in the southern part of the exposure and are designated as Sample A (139-1-5A). Samples of younger rocks were collected as Samples B through E (139-1-5D through E). Sample C represents a 6 foot interval of grayish red, interbedded shales and siltstones overlying Sample B. The beds are from 0.25 inch to 8 inches thick. Mica flakes are scattered throughout this unit.

Attitude of Bedding: N50E, 20N

Sampled Interval: Composite sample of entire unit.

Type of Material: Shale and siltstone

Ceramic Testing Laboratory: Norris

Chemical Analysis:

Analyst: McCreath	%
L.O.I. @ 1,000°C	NA
H_2O Loss @ 110°C	NA
Combined H_2O	3.29
SiO_2	50.39
Al_2O_3	17.38
Fe_2O_3	7.06
FeO	0.58
CaO	3.75
MgO	2.72
CO_2	3.32
Na_2O	5.24
K_2O	3.46
TiO_2	0.83
P_2O_5	NA
MnO	NA
S (total)	$<$ 0.02
C (total)	0.07

Mineralogy (X-ray):

	%	*Accuracy* (±%)
Quartz	16	5
Mica	33	6
Kaolinite	12	7
C-V-Mo	7	3
Feldspar	17	3

Remarks: Carbonates present

Other Properties:

pH: 9.40
P.C.E.: NA
Water of Plasticity (%): 20.0
Drying Shrinkage (%): 3.0
Dry Strength: Good
Drying Characteristics: Good, slight warping, slight scum
Workabiilty: Short working, smooth, fatty

Slow-Firing Tests:

Temp. °F	*Color*	*Hardness*	*% Shk.*	*% Absorb.*	*% App. Por.*	*Approx. Sp. Gr.*
1800	Reddish tan	Fair hard	3.5	4.9	—	2.62
1900	Reddish tan	Fair hard	3.5	4.8	—	2.60
2000	Brown	Hard	3.5	7.3	—	2.25
2100	Melted					
2200						
2300						

Pyrometric cone equivalent: NA **Bloating test:** Positive

Remarks: Poor color, dull, too soft, melts below 1200°F., bloats at 2050°F.

Bloating Tests (Quick-Firing):
Crushing characteristics: Shaly Particle size: —¾" + ½"
Drying characteristics: Good Retention time: 15 minutes

Temp. °F	*Bulk Density*	*Lb/Ft³*	*% Absorb.*	*Remarks*
1800	—	—	—	
1900	2.41	150	2.5	No expansion
2000	1.54	96	1.6	Fair expansion—layered
2100	0.96	60	1.1	Very good expansion
2200				Melted
2300				

Recommendations: Very good lightweight aggregate possibility.

ROTARY KILN TESTS:

Raw Material:
Screen Analysis (Crushed through a hammermill with 1½" screen)

Size	*Percent Retained*
—¾" + ½"	29.4
—½" + ⅜"	16.9
—⅜" + 4 mesh	23.9
—4 mesh + 8 mesh	6.3
—8 mesh PAN	23.5
TOTAL	100.0

Crushing loss (—4 mesh) 29.8%

Fragment shape: Angular

Firing Data:
Size range of feed: —¾ + 4 mesh Pour weight of feed: 82.0 lb/ft³
Bloating temperature: 2020°F
Logging temperature* (*Nodules sticking together): 2060°F

Fired Material (all fired material crushed through a roll crusher)
Screen Analysis* (*ASTM Designation C 311-59T) in percentages by weight passing sieves:

Size designation	¾"	½"	⅜"	No. 4	No. 8	No. 16	No. 50	No. 100
Fine	—	—	100.0	63.0	—	23.0	8.5	5.5
Coarse	100.0	73.0	43.0	5.0	1.6	—	—	—

Loose pour weight* (*ASTM Designation C 311-59T):
Fine: 70.0 lb/ft³ Coarse: 62.5 lb/ft³

COMMENTS: Tabular fragments; mostly non-bloating material. Not promising for lightweight aggregate.

Other Tests: Soluble Br. K. 1.20

Potential Uses: No designated ceramic use. Quick firing tests suggest this material has very good lightweight aggregate potential. However, when this sample was tested along with Sample 139-1-5B and C as a composite sample in the rotary kiln, the results indicated it was not promising for lightweight aggregate production, especially after removing overlying units as overburden.

Remarks: Samples 139-1-5A, 139-1-5B, and 139-1-5C collected as one sample for rotary kiln tests. See rotary kiln data for Sample 139-1-5A for results of these tests.

ADAMS COUNTY Butler Twp.

Sample Number
139-1-5D

Quadrangle: Gettysburg 15′; Biglerville 7½′

Location: Road exposure about 1.5 miles southeast of Biglerville or about 0.5 mile northwest of Table Rock, Pa., along the east side of a paved road (1944 edition of Biglerville 7½′ Quadrangle shows this as an unimproved road).

Geologic Unit: Heidlersburg Member, Gettysburg Formation, Triassic.

Description: Five samples of slightly different lithologies were collected at this exposure to determine whether these compositional differences would be reflected in use potential trends. The oldest beds sampled occur in the southern part of the exposure and are designated as Sample A (139-1-5A). Samples of younger rocks were collected as Samples B through E (139-1-5B through E). Sample D is a medium gray to greenish gray, thin-bedded, pyritic shale, representing 5 stratigraphic feet. This sample is separated from Sample C by an unexposed interval of 10 feet.

Attitude of Bedding: N50E, 20N

Sampled Interval: Composite of unit.

Type of Material: Shale

Ceramic Testing Laboratory: Norris

Chemical Analysis:

Analyst: McCreath	%
L.O.I. @ 1,000°C	NA
H_2O Loss @ 110°C	NA
Combined H_2O	3.84
SiO_2	48.55
Al_2O_3	17.47
Fe_2O_3	3.75
FeO	3.52
CaO	3.04
MgO	4.46
CO_2	4.59
Na_2O	5.04
K_2O	3.11
TiO_2	0.83

Mineralogy (X-ray):

	%	Accuracy (±%)
Quartz	13	5
Mica	36	6
Kaolinite	8	6
C-V-Mo	10	3
Feldspar	18	3

Remarks: Carbonate present

Other Properties:

pH: 9.30
P.C.E. NA
Water of Plasticity (%): 17.0
Drying Shrinkage (%): 2.0

Chemical Analysis:

Analyst: McCreath	%
P_2O_5	NA
MnO	NA
S (total)	< 0.90
C (total)	0.08

Other Properties:

Dry Strength: Fair
Drying Characteristics: Fair, slight warping, slight scum
Workability: Short working, smooth, fatty

Slow-Firing Tests:

Temp. °F	*Color*	*Hardness*	*% Shk.*	*% Absorb.*	*% App. Por.*	*Approx. Sp. Gr.*
1800	Tan	Fair hard	2.5	4.7	—	2.59
1900	Reddish tan	Hard	2.5	3.8	—	2.60
2000	Reddish tan	Hard	4.0	5.1	—	2.50
2100	Melted					
2200						
2300						

Pyrometric cone equivalent: NA **Bloating test:** Positive

Remarks: Fair color, soft, melts below 2100°F. Addition of barium salts would improve luster. Bloats at 2050°F.

Bloating Tests (Quick-Firing):

Crushing characteristics Shaly Particle size: —¾" + ½"
Drying characteristics Good Retention time: 15 minutes

Temp. °F	*Bulk Density*	*Lb/Ft³*	*% Absorb.*	*Remarks*
1800	—	—	—	
1900	2.69	168	2.1	No expansion
2000	0.69	43	3.9	Fine expansion—very short bloating range
2100				Melted
2200				
2300				

Recommendations: None given.

ROTARY KILN TESTS:

Raw Material:

Screen Analysis (Crushed through a hammermill with 1½" screen)

Size		*Percent Retained*
—¾"	+ ½"	36.2
—½"	+ ⅜"	16.9
—⅜"	+ 4 mesh	21.9
—4 mesh	+ 8 mesh	6.4
—8 mesh	PAN	18.6
	TOTAL	100.0

Crushing loss (—4 mesh) 25.0%

Fragment shape: Angular platy

Firing Data:

Size range of feed: —¾ + 4 mesh   Pour weight of feed: 89.0 lb/ft^3

Bloating temperature: 1980°F

Logging temperature* (*Nodules sticking together): 2020°F

Fired Material (all fired material crushed through a roll crusher)
Screen Analysis* (*ASTM Designation C 311-59T) in percentages by weight passing sieves:

Size designa-tion	¾″	½″	⅜″	No. 4	No. 8	No. 16	No. 50	No. 100
Fine	—	—	100.0	64.0	—	20.0	6.4	4.0
Coarse	100.0	82.0	54.0	10.0	2.7	—	—	—

Loose pour weight* (*ASTM Designation C 311-59T):
Fine: 55.0 lb/ft^3 Coarse: 52.5 lb/ft^3

COMMENTS: Not promising for lightweight aggregate; undesirable fragment shape of final product; flat plates. NOTE: This sample is a composite of Samples 139-1-5D and E.

Other Tests: Soluble Br. K. 1.00.

Potential Uses: NW Grade face brick.

Remarks: Sample 139-1-5D and 139-1-5E collected as one sample for rotary kiln tests.

ADAMS COUNTY   Butler Twp.

Sample No.
139-1-5E

Quadrangle: Gettysburg 15′; Biglerville 7½′

Location: Road exposure about 1.5 miles southeast of Biglerville or about 0.5 mile northwest of Table Rock, Pa., along the east side of a paved road (1944 edition of Biglerville 7½′ Quadrangle shows this as an unimproved road).

Geologic Unit Heidlersburg Member, Gettysburg Formation, Triassic.

Description: Five samples of slightly different lithologies were collected at this exposure to determine whether these compositional differences would be reflected in use potential trends. The oldest beds sampled occur in the southern part of the exposure and are designated as Sample A (139-1-5A). Samples of younger rocks were collected as Samples B through E (139-1-5B through E). Sample E consists of grayish red to very dusky red siltstone interbedded with red and green mudstone and a minor greenish gray siltstone, representing 10 stratigraphic feet overlying sample D.

Attitude of Bedding: N50E, 20N

Sampled Interval: Sample is a composite of 10 stratigraphic feet.

Type of Material: Siltstone

Ceramic Testing Laboratory: Norris

Chemical Analysis:

Analyst: McCreath	%
L.O.I. @ 1,000°C	NA
H_2O Loss @ 110°C	NA
Combined H_2O	3.77
SiO_2	50.47
Al_2O_3	18.07
Fe_2O_3	6.21
FeO	0.95
CaO	4.17
MgO	3.10
Co_2	3.94
Na_2O	3.64
K_2O	3.70
TiO_2	0.83
P_2O_5	NA
MnO	NA
S (total)	< 0.04
C (total)	0.10

Mineralogy (X-ray)

	%	Accuracy (±%)
Quartz	15	5
Mica	40	6
Kaolinite	10	7
C-V-Mo	9	3
Feldspar	16	3

Remarks: Carbonate present

Other Properties:

pH: 9.30
P.C.E.: NA
Water of Plasticity (%): 22.0
Drying Shrinkage (%): 3.0
Dry Strength: Good
Drying Characteristics: Good, slight scum
Workability: Short working, smooth, fatty

Slow-Firing Tests:

Temp. °F	*Color*	*Hardness*	*% Shk.*	*% Absorb.*	*% App. Por.*	*Approx. Sp. Gr.*
1800	Tan	Fair hard	4.5	4.2	—	2.62
1900	Tan	Hard	4.5	4.5	—	2.54
2000	Tan	Hard	4.5	5.4	—	2.57
2100	Melted					
2200						
2300						

Pyrometric cone equivalent: NA **Bloating test:** Positive

Remarks: Poor color, soft, melted below 2100°F., bloating at 2050°F. Color and luster need improving.

Bloating Tests (Quick-Firing):

Crushing characteristics Good Particle size: —¾″ + ½″
Drying characteristics Good Retention time: 15 minutes

Temp. °F	*Bulk Density*	*Lb/Ft³*	*% Absorb.*	*Remarks*
1800	—	—	—	
1900	2.62	164	2.0	Very slight expansion
2000	1.41	88	3.1	Fair expansion
2100	0.98	61	1.7	Very good expansion—good skin 2100°F slightly over-fired.
2200				Melted
2300				

Recommendations: Good lightweight aggregate possibility.

Other Tests: Soluble Br. K. 1.00

Potential Uses: No designated ceramic use. Rotary kiln tests of composite sample of Samples 139-1-5D and E indicate these materials are not promising as raw material for lightweight aggregate production. Quick firing tests indicate, however, that sample 139-1-5E has good potential for lightweight aggregate. If sufficient acreage could be outlined, Unit E should probably be further sampled for rotary kiln testing.

Remarks: Sample 139-1-5D and E collected as one sample for rotary kiln tests. See rotary kiln data for sample 139-1-5D for results of these tests.

ADAMS COUNTY Straban Twp.

Sample No.
139-4-6

Quadrangle: Gettysburg 15′; Biglerville 7½′

Location: Road exposure east of Rook Creek on the north side of Pa. Route 394 about 0.2 mile west of U.S. Route 15.

Geologic Unit: Gettysburg Formation, Triassic

Description: Fairly fresh grayish red (10 R 4/2) to dark-reddish brown shale is exposed for a distance of about 170 feet along the road. The beds are ⅛ inch to 7 inches thick. The thinner beds, due to weathering, are fissile and fragments are irregular and platy in shape, generally not exceeding several inches in length. Fragments from the more massive beds are usually tubular in shape and up to seven inches long. The height of the exposure is 15 feet. The sample was collected from the eastern part of the exposure and represents about 20 stratigraphic feet.

Attitude of Bedding: N30, 32N

Sampled Interval: Composite of 20 stratigraphic feet.

Type of Material: Shale

Ceramic Testing Laboratory: Norris

Chemical Analysis:

Analyst: McCreath	%
L.O.I. @ 1,000°C	NA
H_2O Loss @ 110°C	NA
Combined H_2O	3.47
SiO_2	60.80
Al_2O_3	15.92
Fe_2O_3	6.41
FeO	0.32
CaO	1.12
MgO	2.66
CO_2	0.84
Na_2O	4.31
K_2O	2.38
TiO_2	0.86
P_2O_5	NA
MnO	NA
S (total)	< 002
C (total)	006

Mineralogy (X-ray):

	%	Accuracy (±%)
Quartz	27	5
Mica	34	6
Kaolinite	5	3
C-V-Mo	9	3
Feldspar	16	3

Remarks:

Other Properties:

pH: 9.30
P.C.E.: NA
Water of Plasticity (%): 22.0
Drying Shrinkage (%): 3.0
Dry Strength: Good
Drying Characteristics: Good, slight scum
Workability: Short working, smooth, fatty

Slow-Firing Tests:

Temp. °F	*Color*	*Hardness*	*% Shk.*	*% Absorb.*	*% App. Por.*	*Approx. Sp. Gr.*
1800	Light red brown	Fair hard	4.5	5.1	—	2.64
1900	Light red brown	Hard	4.5	4.6	—	2.61
2000	Reddish brown	Hard	7.5	7.9	—	2.56
2100	Melted					
2200						
2300						

Pyrometric cone equivalent: NA **Bloating test:** Negative

Remarks: Fair color, scum, soft; addition of barium salts would improve color and luster.

Bloating Tests (Quick-Firing): (Not run)

Recommendations: Soft brick

ROTARY KILN TESTS:

Raw Material:

Screen Analysis (Crushed through a hammermill with 1½″ screen)

Size		*Percent Retained*
—¾″	+ ½″	17.9
—½″	+ ⅜″	11.7
—⅜″	+ 4 mesh	30.3
—4 mesh	+ 8 mesh	11.0
—8 mesh	PAN	29.1
	TOTAL	100.0

Crushing loss (—4 mesh) 40.1%

Fragment shape: Thin plates

Firing Data:

Size range of feed: —¾ + 4 mesh Pour weight of feed: 90.0 lb/ft³

Bloating temperature: 2000°F

Logging temperature* (*Nodules sticking together): 2020°F

Fired Material (all fired material crushed through a roll crusher)

Screen Analysis* (*ASTM Designation C 311-59T) in percentages by weight passing sieves:

Size designation	¾″	½″	⅜″	No. 4	No. 8	No. 16	No. 50	No. 100
Fine	—	—	100.0	86.0	—	45.0	28.6	15.4
Coarse	100.0	80.0	58.0	15.8	0.8	—	—	—

Loose pour weight* (*ASTM Designation C 311-59T):

Fine: 70.0 lb/ft³ Coarse: 62.5 lb/ft³

Color: Brown

COMMENTS: Not promising for lightweight aggregate; short firing range; angular and tabular fragments; fair crushing; fine pores; heavy; short firing range.

Other Tests: Soluble Br. K. 0.53

Potential Uses: NW Grade face brick

ADAMS COUNTY Straban Twp.

Sample Number
139-4-7A

Quadrangle: Gettysburg 15′; Biglerville 7½′

Location: Road cut exposure 3 miles southeast of Biglerville, Pa. on the east side of Pa. Route 394 and immediately north of a northeast-trending farm lane.

Geologic Unit: Heidlersburg Member, Gettysburg Formation, Triassic

Description: Green gray (5 GY 6/1) and dark green, slightly to moderately weathered shales and mudstones in beds ranging in thickness from fissile up to 7 inches. The base of the sampling site is at the intersection of the public road with the farm lane.

Attitude of Bedding: N35E, 28N

Sampled Interval: Composite of outcrop

Type of Material: Shale

Ceramic Testing Laboratory: Tuscaloosa

Chemical Analysis:

Analyst: Conwell	%
L.O.I. @ 1,000°C	6.43
H_2O Loss @ 110°C	0.78
Combined H_2O	3.67
SiO_2	52.90
Al_2O_3	17.96
Fe_2O_3	7.78
FeO	1.30
CaO	2.62
MgO	3.44
CO_2	1.66
Na_2O	3.30
K_2O	2.78
TiO_2	0.78
P_2O_5	NA
NnO	NA
S (total)	None
C (total)	0.49

Mineralogy (X-ray):

	%	*Accuracy* (±%)
Quartz	17	5
Mica	44	6
Kaolinite	0	—
C-V-Mo	17	3
Feldspar	17	2

Remarks:

Other Properties:

pH: 8.80
P.C.E. NA
Water of Plasticity (%): 19.7
Drying Shrinkage (%): 2.5
Dry Strength: Low
Drying Characteristics: No defects
Workability: Low plasticity

Slow-Firing Tests:

Temp. °F	*Color*	*Hardness*	*% Shk.*	*% Absorb.*	*% App. Por.*	*Approx. Sp. Gr.*
1800	Tan	2	2.5	22.4	37.4	1.67
1900	Tan	2	2.5	20.3	34.9	1.72
2000	Brown	4	5.0	6.5	12.9	1.98
2100	Expanded	—	—	—	—	—
2200	——	—	—	—	—	—
2300	——	—	—	—	—	—

Pyrometric cone equivalent: NA **Bloating test:** Negative

Remarks: Abrupt vitrification; may be limy.

Other Tests: Highly effervescent with HCl

Potential Uses: No designated ceramic use.

ADAMS COUNTY Straban Twp.

Sample Number
139-4-7B

Quadrangle: Gettysburg 15′; Biglerville 7½′

Location: Road cut exposure 3 miles southeast of Biglerville, Pa., on east side of Pa. Route 394, and immediately south of a northeast-trending farm lane.

Geologic Unit: Heidlersburg Member, Gettysburg Formation, Triassic Age

Description: Predominantly grayish red (10 R 4/2) with some greenish gray (5 GY 6/1) to dark-greenish gray (5 GY 4/1) interbedded silty shales, shales, and mudstones occurring on the south-side of a farm lane for a stratigraphic distance of 9 feet. The beds are thin-bedded to massive, and range from fissile up to 12 inches thick. The rock is slightly to moderately weathered.

Attitude of Bedding: N35E, 28N

Sampled Interval: Channel sample of 9 stratigraphic feet.

Type of Material: Shale, silty shale, mudstone

Ceramic Testing Laboratory: Norris

Chemical Analysis:

Analyst: McCreath	%
L.O.I. @ 1,000°C	NA
H_2O Loss @ 110°C	NA
Combined H_2O	4.42
SiO_2	52.27
Al_2O_3	18.44
Fe_2O_3	5.79
FeO	1.78
CaO	1.85
MgO	2.78
CO_2	1.74
Na_2O	4.07
K_2O	4.28
TiO_2	0.78
P_2O_5	NA
MnO	NA
S (total)	< 0.02
C (total)	0.08

Mineralogy (X-ray):

	%	*Accuracy (±%)*
Quartz	20	5
Mica	31	6
Kaolinite	9	6
C-V-Mo	12	3
Feldspar	18	3

Remarks:

Other Properties:

pH: 9.25

P.C.E. NA

Water of Plasticity (%): 16.5

Drying Shrinkage: (%): 3.0

Dry Strength: Fair

Drying Characteristics: Fair, slightly rough, slight scum

Workability: Short working, smooth, fatty

Slow-Firing Tests:

Temp. °F	Color	Hardness	% Shk.	% Absorb.	% App. Por.	Approx. Sp. Gr.
1800	Pale brown	Soft	4.0	4.9	—	2.60
1900	Pale brown	Fair hard	4.5	5.3	—	2.64
2000	Pale brown	Fair hard	5.0	7.5	—	2.60
2100	Melted		—	—	—	—
2200						
2300						

Pyrometric cone equivalent: NA **Bloating test:** Positive

Remarks: Poor color; too soft; melted at 2100°F

Bloating Tests (Quick-Firing):

Crushing characteristics Shaly Particle size: —¾" + ½"
Drying characteristics Good Retention time: 15 minutes

Temp. °F	Bulk Density	Lb/Ft^3	% Absorb.	Remarks
1800	—	—	—	
1900	2.09	130	1.4	Very slight expansion
2000	1.50	94	1.9	Fair expansion
2100	1.01	63	2.1	Good expansion-fair skin
2200				Melted
2300				

Recommendations: Good lightweight aggregate possibility

ROTARY KILN TESTS:

Raw Material:

Screen Analysis (Crushed through a hammermill with 1½" screen)

Size		Percent Retained
—¾"	+ ½"	33.0
—½"	+ ⅜"	16.4
—⅜"	+ 4 mesh	23.1
—4 mesh	+ 8 mesh	6.9
—8 mesh	PAN	20.6
	TOTAL	100.0

Crushing loss (—4 mesh) 27.5%

Fragment shape: Angular

Firing Data:

Size range of feed: —¾ + 4 mesh Pour weight of feed: 84.0 lb/ft^3
Bloating temperature: 1940°F
Logging temperature* (*Nodules sticking together): 1970°F

Fired Material (all fired material crushed through a roll crusher)

Screen Analysis* (*ASTM Designation C 311-59T) in percentages by weight passing sieves:

Size designation	¾″	½″	⅜″	No. 4	No. 8	No. 16	No. 50	No. 100
Fine	—	—	100.0	72.0	—	32.0	11.6	6.1
Coarse	100.0	84.0	52.0	10.0	3.2	—	—	—

Loose pour weight* (*ASTM Designation C 311-59T):
Fine: 62.5 lb/ft^3 Coarse: 57.5 lb/ft^3

COMMENTS: Not promising for lightweight aggregate; short firing range; angular and tabular fragments; fine pores; short range; mixture of bloating and nonbloating material; heavy.

Other Tests: Soluble Br. K. 1.00

Potential Uses: No designated ceramic use.

ADAMS COUNTY Mount Pleasant Twp.

Sample Number
139-5-12A

Quadrangle: Gettysburg 15′; Hampton 7½′

Location: Exposed about 1.8 miles south-southwest of New Chester, Pa., and about 0.1 mile east of Swift Run along the northeast side of an unimproved road trending northwest-southeast across Mount Pleasant Township.

Geologic Unit: Gettysburg Formation, Triassic

Description: Three samples of somewhat different lithologies were collected at this exposure to determine whether compositional differences would be reflected in use trends. The exposure extends for a distance of about 120 feet along the road and measures about 8 feet in height. Sample A (139-5-12A) is a dusty yellow (5 Y 6/4), thin bedded to fissile shale representing 5 stratigraphic feet in the upper part of the northwest portion of the exposure. A few silty shales and shaly siltstone beds, several inches thick, are interbedded with the moderately weathered shale.

Attitude of Bedding: N20-25E, 27N

Sampled Interval: Channel sample of 5 stratigraphic feet.

Type of Material: Shale

Ceramic Testing Laboratory: Norris

Chemical Analysis:

Analyst: McCreath

	%
L.O.I. @ 1,000°C	NA
H_2O Loss @ 110°C	NA
Combined H_2O	6.27
SiO_2	55.61
Al_2O_3	18.80
Fe_2O_3	8.29
FeO	0.65

Mineralogy (X-ray):

	%	Accuracy (±%)
Quartz	27	5
Mica	37	6
Kaolinite	0	—
C-V-Mo	17	4
Feldspar	4	2

Remarks:

Chemical Analysis:

Analyst: McCreath	%
CaO	0.97
MgO	2.63
CO_2	0.21
Na_2O	1.39
K_2O	3.11
TiO_2	0.98
P_2O_5	NA
MnO	NA
S (total)	< 0.01
C (total)	0.02

Other Properties:

pH: 8.00
P.C.E.: NA
Water of Plasticity (%): 24.0
Drying Shrinkage (%): 5.0
Dry Strength: Good
Drying Characteristics: Good, slight crazing
Workability: Fairly long working, smooth, plastic, fatty

Slow-Firing Tests:

Temp. °F	*Color*	*Hardness*	*% Shk.*	*% Absorb.*	*% App. Por.*	*Approx. Sp. Gr.*
1800	Tan	Fair hard	5.5	5.1	—	2.67
1900	Red tan	Hard	7.5	7.0	—	2.61
2000	Red brown	Very hard	10.0	9.3	—	2.54
2100	Dark brown	Steel hard	12.0	17.6	—	2.52
2200	Very dark brown	Very hard	0	1.0	—	2.20
2300	Melted		—	—	—	—

Pyrometric cone equivalent: NA **Bloating test:** Positive

Remarks: Good color, slight scum, expands at about 2150°F. Addition of barium salts would remove scum.

Bloating Tests (Quick-Firing):
Crushing characteristics: Good Particle size: —¾" + ½"
Drying characteristics Good Retention time: 15 minutes

Temp. °F	*Bulk Density*	*Lb/Ft³*	*% Absorb.*	*Remarks*
1800	2.67	167	1.4	No expansion
1900	2.43	152	3.3	Very slight expansion
2000	1.13	71	3.0	Fair expansion-uneven
2100				Melted; sticky
2200				
2300				

Recommendations: Too short bloating range for lightweight aggregate. Might consider sintering

Other Tests: Soluble Br. K. 1.01

Potential Uses: Face brick, pottery; quick-firing tests indicate not suited for rotary kiln lightweight aggregate but might be used for sintering.

ADAMS COUNTY Mount Pleasant Twp.

Sample Number
139-5-12B

Quadrangle: Gettysburg 15′; Hampton 7½′

Location: Road exposure about 1.8 miles south-southwest of New Chester, Pa., and about 0.1 mile east of Swift Run along the northeast side of an improved road trending northwest-southeast across Mount Pleasant Township.

Geologic Unit: Gettysburg Formation, Triassic

Description: Three samples of somewhat different lithologies were collected at this exposure to determine whether compositional differences would be reflected in use trends. The exposure extends for a distance of about 120 feet along the road and measures about 8 feet in height. Sample B (139-5-12B) is a grayish green (10 G 4/2) to dark-greenish gray (5 G 4/1) calcareous shale and represents a stratigraphic interval of 2 feet. Sample B stratigraphically underlies Sample A (139-5-12A) and is slightly to moderately weathered.

Attitude of Bedding: N20-25E, 27N

Sampled Interval: Channel sample of 2 stratigraphic feet.

Type of Material: Shale

Ceramic Testing Laboratory: Norris

Chemical Analysis:

Analyst: McCreath	%
L.O.I. @ 1,000°C	NA
H_2O Loss @ 110°C	NA
Combined H_2O	4.95
SiO_2	50.27
Al_2O_3	16.42
Fe_2O_3	6.68
FeO	1.17
CaO	5.82
MgO	2.87
CO_2	4.51
Na_2O	1.05
K_2O	3.07
TiO_2	0.98
P_2O_5	NA
MnO	NA
S (total)	< 0.01
C (total)	0.12

Mineralogy (X-ray):

	%	Accuracy (±%)
Quartz	24	5
Mica	33	6
Kaolinite	19	7
C-V-Mo	7	3
Feldspar	2	1

Remarks: Carbonate present

Other Properties:

pH: 9.00
P.C.E. NA
Water of Plasticity (%): 21.0
Drying Shrinkage (%): 5.0
Dry Strength: Good
Drying Characteristics: Fair, crazing, slightly rough
Workability: Short working, fairly smooth, fatty

Slow-Firing Tests:

Temp. °F	*Color*	*Hardness*	*% Shk.*	*% Absorb.*	*% App. Por.*	*Approx. Sp. Gr.*
1800	Tan	Fair hard	4.5	4.4	—	2.63
1900	Tan	Fair hard	5.0	4.8	—	2.58
2000	Tan	Hard	5.0	5.1	—	2.59
2100	Very dark brown	Hard	11.0	8.7	—	2.45
2200	Melted	—	—	—	—	—
2300						

Pyrometric cone equivalent: NA **Bloating test:** Negative

Remarks: Fair color, rough, slight scum, a little soft.

Bloating Tests (Quick-Firing): NA

Other Tests: Soluble Br. K. 1.00

Potential Uses: NW Grade face brick

ADAMS COUNTY Mount Pleasant Twp.

Sample Number
139-5-12C

Quadrangle: Gettysburg 15′; Hampton 7½′

Location: Road exposure about 1.8 miles south-southwest of New Chester, Pa. and about 0.1 mile east of Swift Run along the northeast side of an unimproved road trending northwest-southeast across Mount Pleasant Township.

Geologic Unit: Gettysburg Formation, Triassic

Description: Three samples of somewhat different lithologies were collected at this exposure to determine whether compositional differences would be reflected by use. The exposure extends for a distance of about 120 feet along the road and measures about 8 feet in height. Sample C (139-5-12C) consists af grayish red (10 R 4/2) fissile shales underlying Sample B (139-5-12B) and represents 11 stratigraphic feet. An 18 inch sequence of siltstone beds occurs about 6 feet from the top of the unit. The slightly to moderately weathered shale breaks into small, platy fragments.

Attitude of Bedding: N20-25E, 27N

Sampled Interval: Channel sample of 11 stratigraphic feet.

Type of Material: Shale

Ceramic Testing Laboratory: Norris

Chemical Analysis:

Analyst: McCreath	%
L.O.I. @ 1,000°C	NA
H_2O Loss @ 110°C	NA
Combined H_2O	4.49
SiO_2	53.95
Al_2O_3	16.77
Fe_2O_3	8.48
FeO	0.32
CaO	2.69
MgO	2.67
CO_2	1.95
Na_2O	1.47
K_2O	3.81
TiO_2	0.98
P_2O_5	NA
MnO	NA
S (total)	$<$ 0.01
C (total)	0.05

Mineralogy (X-ray):

	%	Accuracy (±%)
Quartz	22	5
Mica	43	7
Kaolinite	6	5
C-V-Mo	7	3
Feldspar	2	1
Remarks:		

Other Properties:

pH: 9.20
P.C.E.: NA
Water of Plasticity (%): 21.0
Drying Shrinkage (%): 5.0
Dry Strength: Good
Drying Characteristics: Good
Workability: Short working, fairly smooth, fatty

Slow-Firing Tests:

Temp. °F	Color	Hardness	% Shk.	% Absorb.	% App. Por.	Approx. Sp. Gr.
1800	Light brown	Fair hard	4.0	5.4	—	2.64
1900	Light brown	Hard	4.5	5.0	—	2.61
2000	Reddish brown	Very hard	6.0	8.1	—	2.58
2100	Very dark brown	Steel hard	9.5	13.9	—	2.29
2200	Melted	—	—	—	—	—
2300						

Pyrometric cone equivalent: NA **Bloating test:** Positive

Remarks: Fair color, short firing range for brick; color needs improving.

Bloating Tests (Quick-Firing): NA

Other Tests: Soluble Br. K. 0.54

Potential Uses: Face brick, tile

ADAMS COUNTY Mount Joy Twp.

Sample Number
139-7-8

Quadrangle: Gettysburg 15′; Gettysburg 7½′

Location: Road cut exposure on north side of U. S. Route 140 about 3.2 miles southeast of Gettysburg, Pa., just west of an unimproved road paralleling the west side of White Plum Run that intersects U. S. Route 140 from the northeast.

Geologic Unit: Gettysburg Formation, Triassic

Description: Grayish red (5 R 4/2) massive appearing shales represent about 25 stratigraphic feet of the exposure. Some siltstone and conglomerate are interbedded with the shale in other unsampled portions of the exposure. Fragments of shale at the base and on the slope of the slightly weathered exposure are platy and rarely exceed several inches in length.

Attitude of Bedding: N20W, 22S

Sampled Interval: Composite sample of 25 stratigraphic feet.

Type of Material: Shale

Ceramic Testing Laboratory: Norris

Chemical Analysis:

Analyst: McCreath	%
L.O.I. @ 1,000°C	NA
H_2O Loss @ 110°C	NA
Combined H_2O	4.04
SiO_2	54.14

Mineralogy (X-ray):

	%	Accuracy (±%)
Quartz	26	5
Mica	34	6
Kaolinite	11	7
C-V-Mo	8	3

Chemical Analysis:

Analyst: McCreath	%
Al_2O_3	17.06
Fe_2O_3	7.79
FeO	0.30
CaO	3.33
MgO	3.30
CO_2	2.35
Na_2O	2.45
K_2O	3.14
TiO_2	1.00
P_2O_5	NA
MnO	NA
S (total)	< 0.01
C (total)	0.07

Mineralogy (X-ray):

	%	Accuracy (±%)
Feldspar	11	3

Remarks: Carbonate present

Other Properties:

pH: 9.30
P.C.E.: NA
Water of Plasticity (%): 2.10
Drying Shrinkage (%): 5.0
Dry Strength: Fair
Drying Characteristics: Fair, slight warping, slight scum
Workability: Short working, fairly smooth, fatty

Slow-Firing Tests:

Temp. °F	*Color*	*Hardness*	*% Shk.*	*% Absorb.*	*% App. Por.*	*Approx. Sp. Gr.*
1800	Light brown	Fair hard	4.5	5.0	—	2.69
1900	Light brown	Fair hard	4.5	5.2	—	2.63
2000	Brown	Hard	5.0	8.5	—	2.57
2100	Very dark brown	Very hard	2.0	4.0	—	1.71
2200	Melted	—	—	—	—	—
2300						

Pyrometric cone equivalent: NA **Bloating test:** Positive

Remarks: Fair color, dull, soft; color needs improving.

Bloating Tests (Quick-Firing):
Crushing characteristics Good Particle size: —¾″ + ½″
Drying characteristics Good Retention time: 15 minutes

Temp. °F	*Bulk Density*	*Lb/Ft³*	*% Absorb.*	*Remarks*
1800	—	—	—	
1900	2.60	162	2.2	No expansion
2000	2.46	154	2.6	Very little expansion
2100	2.00	125	2.7	Poor expansion
2200				Melted
2300				

Recommendations: Too heavy for lightweight aggregate possibility

Other Tests: Soluble Br. K. 0.54

Potential Uses: NW Grade face brick

ADAMS COUNTY Mount Joy Twp.

Sample Number
139-10-10

Quadrangle: Taneytown 15′; Taneytown 7½′

Location: Outcrop along the east side of Pa. Route 134, about 0.5 mile north of the Mason and Dixon line.

Geologic Unit: Gettysburg Formation, Triassic

Description: Dark-reddish brown (10 R ¾), thin-bedded shales are exposed along the road for a distance of 120 feet. Weathering of the shale is slight and the shale fragments at the base of the outcrop are small and platy, rarely exceeding several inches in length. The height of the outcrop is 9 feet.

Attitude of Bedding: N33E, 20N

Sampled Interval: Channel sample of 9 stratigraphic feet.

Type of Material: Shale

Ceramic Testing Laboratory: Norris

Chemical Analysis:

Analyst: McCreath	%
L.O.I. @ 1,000°C	NA
H_2O Loss @ 110°C	NA
Combined H_2O	4.09
SiO_2	57.61
Al_2O_3	17.09
Fe_2O_3	5.89
FeO	0.29
CaO	1.72
MgO	2.81
CO_2	1.42
Na_2O	3.50
K_2O	3.10
TiO_2	0.90
P_2O_5	NA
MnO	NA
S (total)	$<$ 0.01
C (total)	0.09

Mineralogy (X-ray):

	%	Accuracy (±%)
Quartz	25	5
Mica	41	6
Kaolinite	8	6
C-V-Mo	7	3
Feldspar	10	2

Remarks:

Other Properties:

pH: 9.30
P.C.E.: NA
Water of Plasticity (%): 21.0
Drying Shrinkage (%): 4.5
Dry Strength: Good
Drying Characteristics: Good, slight scum
Workability: Short working, fairly smooth, fatty

Slow-Firing Tests:

Temp. °F	Color	Hardness	% Shk.	% Absorb.	% App. Por.	Approx. Sp. Gr.
1800	Light brown	Fair hard	4.5	4.9	—	2.66
1900	Light brown	Fair hard	4.5	5.8	—	2.61
2000	Brown	Hard	6.0	9.8	—	2.56
2100	Very dark brown	Very hard	0.5	broken	—	1.60
2200	Melted	—	—	—	—	—
2300						

Pyrometric cone equivalent: NA **Bloating test:** Positive

Remarks: Fair color, slight scum, a little soft. Addition of barium salts would improve.

Bloating Tests (Quick-Firing):

Crushing characteristics: Good — Particle size: —¾" + ½"
Drying characteristics Good — Retention time: 15 minutes

Temp. °F	*Bulk Density*	*Lb/Ft³*	*% Absorb.*	*Remarks*
1800	—	—	—	
1900	2.68	167	2.4	No expansion
2000	2.38	149	2.0	Very slight expansion
2100	1.98	124	2.1	Slight expansion
2200				Melted
2300				

Recommendations: Too heavy for lightweight aggregate.

Other Tests: Soluble Br. K. 1.20

Potential Uses: NW Grade face brick

ADAMS COUNTY Mount Joy Twp.

Sample Number
139-10-11

Quadrangle: Taneytown 15′; Taneytown 7½′

Location: Roadside outcrop on east side of Pa. Route 134, about 1.5 miles north of the Pennsylvania-Maryland line.

Geologic Unit: Gettysburg Formation, Triassic

Description: Predominantly dark reddish-brown, negligibly-to slightly-weathered shales are interbedded with a few beds of siltstones and sandstones in an outcrop which extends about 175 feet along the road and is 10 to 15 feet high. The shale breaks into platy fragments that range from ⅛ to ¼ inch in thickness. The sample represents the upper part of the stratigraphic section at the north end of the outcrop.

Attitude of Bedding: N20-30E, 20-25N

Sampled Interval: Channel sample of 11 stratigraphic feet.

Type of Material: Shale

Ceramic Testing Laboratory: Norris

Chemical Analysis:

Analyst: McCreath	%
L.O.I. @ 1,000°C	NA
H_2O Loss @ 110°C	NA
Combined H_2O	3.89
SiO_2	56.10
Al_2O_3	16.70
Fe_2O_3	6.55
FeO	0.12
CaO	3.21
MgO	2.90

Mineralogy (X-ray):

	%	*Accuracy (±%)*
Quartz	25	5
Mica	49	6
Kaolinite	7	4
C-V-Mo	7	3
Feldspar	2	1

Remarks: Carbonate present.

Chemical Analysis:

Analyst: McCreath	%
CO_2	2.37
Na_2O	1.33
K_2O	3.01
TiO_2	0.87
P_2O_5	NA
MnO	NA
S (total)	< 0.01
C (total)	0.09

Other Properties:

ph: 9.15
P.C.E.: NA
Water of Plasticity (%): 2.10
Drying Shrinkage (%): 4.0
Dry Strength: Good
Drying Characteristics: Fair, wavy, slight scum
Workability: Short working, fairly smooth, fatty

Slow-Firing Tests:

Temp. °F	*Color*	*Hardness*	*% Shk.*	*% Absorb.*	*% App. Por.*	*Approx. Sp. Gr.*
1800	Light brown	Fair hard	4.0	5.5	—	2.64
1900	Light brown	Fair hard	4.0	5.7	—	2.62
2000	Brown	Very hard	7.5	16.0	—	2.14
2100	Melted	—	—	—	—	—
2200						
2300						

Pyrometric cone equivalent: NA **Bloating test:** Negative

Remarks: Fair color, slight scum. Addition of barium salts would improve.

Bloating Tests (Quick-Firing): NA

Other Tests: Soluble Br. K. 1.01

Potential Uses: Face brick at 1950°F

BERKS COUNTY Upper Bern Twp.

Sample Number
176-8-7

Quadrangle: Pottsville 15′; Auburn 7½′

Location: Outcrop on the west side of the road leading north from the west edge of Shartlesville, Pa. The exposure is about 250 feet north of U. S. Route 22 and opposite Stuckey's store (on east side of road).

Geologic Unit: Martinsburg Formation, Ordovician

Description: Predominantly dusty red (10 R 3/2) to grayish red (10 R 4/2) shale with some greenish gray (5 GY 6/1) shale was sampled. The exposure is fresh to moderately weathered. Although there are interbedded siltstones and sandstones in parts of the exposure, sampling was limited to a section of red shale, 40 feet long.

Attitude of Bedding: N40W, 65S

Sampled Interval: Channel sample of 40 feet of section.

Type of Material: Shale

Ceramic Testing Laboratory: Tuscaloosa

Chemical Analysis:

Analyst: Conwell	%
L.O.I. @ 1,000°C	5.61
H_2O Loss @ 110°C	0.31
Combined H_2O	3.54
SiO_2	61.56
Al_2O_3	15.44
Fe_2O_3	5.40
FeO	0.58
CaO	1.81
MgO	4.38
CO_2	1.85
Na_2O	0.68
K_2O	2.76
TiO_2	0.90
P_2O_5	NA
MnO	NA
S (total)	None
C (total)	0.22

Mineralogy (X-ray):

	%	Accuracy (±%)
Quartz	28	5
Mica	54	6
Kaolinite	5	4
C-V-Mo	6	3
Feldspar	2	1

Remarks:

Other Properties:

pH: 7.90
P.C.E.: NA
Water of Plasticity (%): 15.9
Drying Shrinkage (%): 2.5
Dry Strength: Low
Drying Characteristics: No defects
Workability: Low plasticity

Slow-Firing Tests:

Temp. °F	*Color*	*Hardness*	*% Shk.*	*% Absorb.*	*% App. Por.*	*Approx. Sp. Gr.*
1800	Light brown	Moh's 2	2.5	12.7	25.1	1.98
1900	Light brown	Moh's 3	2.5	11.1	22.5	2.03
2000	Brown	Moh's 4	2.5	8.7	18.4	2.11
2100	Dark brown	Moh's 5	2.5	0.5	1.0	1.98
2200	Expanded	—	—	—	—	—

Pyrometric cone equivalent: NA **Bloating test:** Negative

Remarks: Abrupt vitrification. May be limy.

Bloating Tests (Quick-Firing): NA

Other Tests: Slightly effervescent with HCl.

Potential Uses: No designated ceramic use.

BERKS COUNTY Jefferson Twp.

Sample Number
177-2-3

Quadrangle: Wernersville 15′; Straustown 7½′

Location: Road cut exposure along the east side of a light-duty macadam road, about 0.6 mile north-northeast of Kricks Mill, Pa., and 2:15 miles south of New Shaefferstown, Pa.

Geologic Unit: Martinsburg Formation, Ordovician.

Description: Thin-bedded, predominantly moderately yellowish brown (10 YR 5/4) shales with some interbedded gray olive (10 YR 4/2) shales are exposed for a distance of 200 feet along the roadway. Weathering of the shales is moderate. The maximum height of the exposure is 25 feet.

Attitude of Bedding: N75W, 45S

Sampled Interval: Grab sample every five feet across the exposure.

Type of Material: Shale

Ceramic Testing Laboratory: Norris

Chemical Analysis:

Analyst: Spectrochemical	%
L.O.I. @ 1,000°C	5.84
H_2O Loss @ 110°C	0.51
Combined H_2O	NA
SiO_2	63.60
Al_2O_3	15.30
Fe_2O_3	6.63
FeO	1.03
CaO	0.46
MgO	1.14
CO_2	0.26
Na_2O	1.18
K_2O	3.70
TiO_2	0.97
P_2O_5	NA
MnO	NA
S (total)	0.07
C (total)	0.12

Mineralogy (X-ray):

	%	Accuracy (±%)
Quartz	38	5
Mica	44	6
Kaolinite	0	
C-V-Mo	12	3
Feldspar	2	1

Remarks: Mineralogy indicates chemical analysis is low in Al_2O_3.

Other Properties:

pH: 7.60
P.C.E.: NA
Water of Plasticity (%): 24.0
Drying Shrinkage (%): 4.0
Dry Strength: Good
Drying Characteristics: Fair, wavy, rough
Workability: Short working; smooth

Slow-Firing Tests:

Temp. °F	*Color*	*Hardness*	*% Shk.*	*% Absorb.*	*% App. Por.*	*Approx. Sp. Gr.*
1800	Tan	Fair hard	6.0	6.6	—	2.53
1900	Light brown	Hard	5.5	10.9	—	2.80
2000	Brown	Very hard	8.5	16.0	—	2.72
2100	Dark brown	Steel hard	10.5	54.5	—	2.56
2200	Very dark brown	Steel hard	10.5	102.3	—	2.45
2300						

Pyrometric cone equivalent: NA **Bloating test:** Positive

Remarks: Fair color; high shrinkage; very high absorption; wavy rough surface.

Bloating Tests (Quick Firing):

Crushing characteristics: Fair-shaly Particle size: —¾ + ½
Drying characteristics: Good Retention time: 15 minutes

Temp. °F	Bulk Density	Lb/Ft³	% Absorb.	Remarks
1800	—	—	—	
1900	—	—	—	
2000	1.81	113	25.3	Slight local expansion
2100	1.85	115	28.1	Shaly expansion
2200	1.59	99	24.5	Shaly expansion
2300				

Recommendations: Too heavy for lightweight aggregate.

ROTARY KILN TESTS

Raw Material:

Screen Analysis (Crushed through a hammermill with 1½" screen)

Size		Percent Retained
—¾"	+ ½"	30.5
—½"	+ ⅜"	16.1
—⅜"	+ 4 mesh	29.8
—4 mesh	+ 8 mesh	10.2
—8 mesh	PAN	13.4
	TOTAL	100.0

Crushing loss (—4) mesh) 23.6%

Fragment shape: Flat plates

Firing Data:

Size range of feed: —¾ + 4 mesh Pour weight of feed: 88.2 lb/ft³

Bloating temperature: 2040°F

Logging temperature* (*Nodules sticking together): 2080°F

Fired Material (all fired material crushed through a roll crusher)

Screen Analysis* (*ASTM Designation C 311-59T) in percentages by weight passing sieves:

Size designation	¾"	½"	⅜"	No. 4	No. 8	No. 16	No. 50	No. 100
Fine	—	—	100.0	74.2	—	15.1	3.2	1.6
Coarse	100.0	98.0	90.4	46.3	15.2	—	—	—

Loose pour weight* (*ASTM Designation C 311-59T):

Fine: 51.5 lb/ft³ Coarse: 46.8 lb/ft³

COMMENTS: Undesirable fragment shape of fired product (flakes); flat plates; nonporous; poor crushing.

Other Tests: Soluble Br. K. 0.60

Potential Uses: Lightweight aggregate made from this material would probably be of fair quality.

BERKS COUNTY Penn Twp.

Sample Number

177-2-4

Quadrangle: Wernersville 15'; Bernville 7½'

Location: Exposure on the northeast side of Pa. Route 183, about one mile south-southeast of Bernville, Pa.

Geologic Unit: Martinsburg Formation, Ordovician.

Description: Interbedded dark-reddish brown (10 R 3/4), grayish orange (10 YR 7/4) and dark-greenish gray (5 GY 4/1), thin-bedded shales are exposed for about 225 feet along the roadway. The shales are slightly to moderately weathered; the more intense weathering is more apparent in the grayish orange shales. The height of the exposure is 28 feet.

Attitude of Bedding: Variable attitude due to folding; N40-55E, 50-70S

Sampled Interval: Composite of entire exposure.

Type of Material: Shale

Ceramic Testing Laboratory: Norris

Chemical Analysis:

Analyst: Spectrochemical	%
L.O.I. @ 1,000°C	5.13
H_2O Loss @ 110°C	0.23
Combined H_2O	NA
SiO_2	69.60
Al_2O_3	8.70
Fe_2O_3	6.80
FeO	2.20
CaO	1.00
MgO	2.00
CO_2	0.81
Na_2O	1.18
K_2O	2.70
TiO_2	0.59
P_2O_5	NA
MnO	NA
S (total)	0.03
C (total)	0.13

Mineralogy (X-ray):

	%	Accuracy (±%)
Quartz	42	5
Mica	38	6
Kaolinite	0	—
C-V-Mo	12	3
Feldspar	2	1

Remarks: Mineralogy indicates chemical analysis is low in Al_2O_3.

Other Properties:

pH: 8.95
P.C.E.: NA
Water of Plasticity (%): 19.0
Drying Shrinkage (%): 1.0
Dry Strength: Good
Drying Characteristics: Fair; slightly wavy; rough; spotty
Workability: Short-working; smooth

Slow Firing Tests:

Temp. °F	*Color*	*Hardness*	*% Shk.*	*% Absorb.*	*% App. Por.*	*Approx. Sp. Gr.*
1800	Tan	Fair hard	1.0	6.9	—	2.60
1900	Tan	Hard	4.0	7.2	—	2.56
2000	Chocolate	Very hard	5.5	13.0	—	2.42
2100	Dark brown	Steel hard	6.0	24.6	—	2.32
2200	Black	Hard	1.0	113.0	—	1.61
2300	Melted	—	—	—	—	—

Pyrometric cone equivalent: NA **Bloating test:** Positive

Remarks: Fair color; very high absorption; rough surface; slight expansion.

Bloating Tests (Quick-Firing):

Crushing characteristics: Fair-shaly — Particle size —¾ + ½
Drying characteristics: Good — Retention time 15 minutes

Temp. °F	*Bulk Density*	*Lb/Ft³*	*% Absorb.*	*Remarks*
1800	—	—	—	—
1900	—	—	—	—
2000	2.33	145	28.0	No expansion
2100	1.60	100	18.3	Slight expansion—shaly
2200	1.71	107	22.9	Fair expansion—shaly
2300				

Recommendations: Too heavy for lightweight aggregate.

ROTARY KILN TESTS:

Raw Material:

Screen Analysis (Crushed through a hammermill with 1½" screen)

Size		*Percent Retained*
—¾"	+ ½"	37.1
—½"	+ ⅜"	15.0
—⅜"	+ 4 mesh	24.5
—4 mesh	+ 8 mesh	9.9
—8 mesh	PAN	13.5
	TOTAL	100.0

Crushing loss (—4 mesh) 23.4%

Fragment shape: Tabular fragments

Firing Data:

Size range of feed: —¾ + 4 mesh   Pour weight of feed: 92.6 lb/ft³

Bloating temperature: 2080°F

Logging temperature* (*Nodules sticking together): 2110°F

Fired Material (all fired material crushed through a roll crusher)

Screen Analysis* (*ASTM Designation C 311-59T) in percentages by weight passing sieves:

Size designation	¾"	½"	⅜"	No. 4	No. 8	No. 16	No. 50	No. 100
Fine	—	—	100.0	57.8	—	10.3	4.2	3.1
Coarse	100.0	89.3	76.3	38.1	12.4	—	—	—

Loose pour weight* (*ASTM Designation C 311-59T):

Fine: 48.5 lb/ft³   Coarse: 50.0 lb/ft³

COMMENTS: Undesirable fragment shape of fired product (flakes); tabular and flat fragments; fair pore structure; poor crushing.

Other Tests: Soluble Br. K. 1.10

Potential Uses: Probably too heavy for lightweight aggregate. Lightweight aggregate produced from this material would probably be of fair quality.

Remarks: The exposure is located ¼ mile south of Texas Eastern 24 inch gas pipeline and between Samples 177-2-1 and 177-6-2, both of which in tests have shown potential for use for brick, floor tile, and lightweight aggregate. (See O'Neill and others, 1965, p. 75-78).

BERKS COUNTY Heidelberg Twp.

Sample Number
177-5-5

Quadrangle: Wernersville 15′; Sinking Spring 7½′

Location: Collected from bed of small stream on the west side of a secondary road 3.69 miles north-northwest of the square in Wernersville, Pa.

Geologic Unit: Residual clay; from Hershey(?) Formation, Ordovician.

Description: Unknown thickness (greater than one foot) of residual clay on the Hershey Formation is exposed in stream bed, with about 3.5 feet of soil overburden. Similar clay in neraby plowed fields to the southeast (mixed with soil by cultivation) suggests that the deposit may be fairly extensive.

Attitude of Bedding: Beds dip very gently to the south-southeast.

Sampled Interval: Grab sample

Type of Material: Residual Clay

Ceramic Testing Laboratory: Tuscaloosa

Chemical Analysis:

Analyst: Conwell	%
L.O.I. @ 1,000°C*	4.98
H_2O Loss @ 110°C	1.18
Combined H_2O	4.86
SiO_2	66.50
Al_2O_3	17.52
Fe_2O_3	3.44
FeO	0.65
CaO	0.17
MgO	1.39
CO_2	0.02
Na_2O	0.68
K_2O	2.99
TiO_2	0.99
P_2O_5	0.07
MnO	0.04
S (total)	0.00
C (total)	0.18

* Nitrogen atmosphere

Mineralogy (X-ray):

	%	Accuracy (±%)
Quartz	41	5
Mica	39	6
Kaolinite	0	—
C-V-Mo	13	3
Feldspar	2	1

Remarks:

Other Properties:

pH: 5.3
P.C.E.: NA
Water of Plasticity (%): 22.8
Drying Shrinkage (%): 2.5
Dry Strength: Fair
Drying Characteristics: No drying defects
Workability: Low plasticity

Slow-Firing Tests:

Temp. °F	*Color*	*Hardness*	*% Shk.*	*% Absorb.*	*% App. Por.*	*Approx. Sp. Gr.*
1800	Tan	Moh's 3	5.0	18.0	31.9	1.77
1900	Tan	Moh's 4	5.0	14.2	26.7	1.88
2000	Tan	Moh's 4	7.5	11.6	22.9	1.97
2100	Light brown	Moh's 5	10.0	3.5	7.8	2.22
2200	Gray brown	Moh's 6	12.5	0.5	1.2	2.30
2300	Expanded	—	—	—	—	—

Pyrometric cone equivalent: NA **Bloating test:** Negative

Bloating Tests (Quick-Firing): NA

Other Tests: Does not effervesce with HCL.

Semi-quantitative spectrographic analysis showed the following abundance of trace elements: Ba (> 0.1%), Sr, Zr, V (> 0.001 < 0.01%). Other elements such as Zn, Cu, Cr, and Ni, if present, are less than 0.001%.

Potential Uses: Should fire to "MW" face brick specifications at about 2000°F; Structural tile.

BERKS COUNTY Albany Twp.

Sample Number
186-5-3

Quadrangle: Hamburg 15′; Hamburg 7½′

Location: Road cut on the northwest side of Pa. Route 143, about 2.5 miles by road north-northwest of the intersection of Pa. Route 143 and U. S. Route 22.

Geologic Unit: Martinsburg Formation, Ordovician

Description: Thin-bedded to fissile, gray orange, gray red (10 R 4/2), olive gray (5 Y 4/1) and dark-greenish gray (5 GY 4/1) shale that is interbedded locally with sandstone (approximately 15% of the rock). Weathering is moderate in the gray-orange shale and slight to moderate in the red and gray shale. Fragments of the shale are either platy or tabular in shape and up to six inches in length. The exposure is 20 feet high.

Attitude of Bedding: N59E, 60S

Sampled Interval: Grab sample collected along the outcrop.

Type of Material: Shale with some sandstone

Ceramic Testing Laboratory: Norris

Chemical Analysis:

Analyst: Spectrochemical %

L.O.I. @ 1,000°C	5.11
H_2O Loss @ 110°C	0.91
Combined H_2O	NA
SiO_2	67.50
Al_2O_3	13.10
Fe_2O_3	7.61
FeO	0.59
CaO	0.35
MgO	1.58
CO_2	0.23
Na_2O	0.44
K_2O	2.90
TiO_2	0.78
P_2O_5	NA
MnO	NA
S (total)	> 0.01
C (total)	0.02

Mineralogy (X-ray):

	%	Accuracy (±%)
Quartz	32	5
Mica	40	6
Kaolinite	0	—
C-V-Mo	12	3
Feldspar	2	1

Remarks: Mineralogy indicates chemical analysis is low in Al_2O_3. Carbonates present.

Other Properties:

pH: 6.95
P.C.E.: NA
Water of Plasticity (%): 20.8
Drying Shrinkage (%): 0.0
Dry Strength: Good
Drying Characteristics: Good; slight warping
Workability: Mealy; smooth; short-working

Slow-Firing Tests:

Temp. °F	Color	Hardness	% Shk.	% Absorb.	% App. Por.	Approx. Sp. Gr.
1800	Tan	Fair hard	1.0	5.7	—	2.57
1900	Light brown	Hard	4.0	7.2	—	2.52
2000	Red brown	Very hard	6.0	12.2	—	2.49
2100	Red brown	Steel hard	6.0	18.2	—	2.46
2200	Dark brown	Steel hard	10.0	51.7	—	2.36
2300	Melted	—	—	—	—	—

Pyrometric cone equivalent: NA **Bloating test:** Negative

Remarks: Good color, absorption high, slight warping. Addition of alkali would improve workability.

Bloating Tests (Quick-Firing) NA

Other Tests: Soluble Br. K. 0.8

Potential Uses: NW Grade face brick; could be used as MW Grade and SW Grade face brick and tile if waterproofed.

BERKS COUNTY Albany Twp.

Sample Number
186-5-6

Quadrangle: Hamburg 15′; New Tripoli 7½′

Location: Outcrop along the west side of Pa. Route 143, about one mile south of Wanamakers, Pa.

Geologic Unit: Martinsburg Formation, Ordovician

Description: Interbedded, thin-bedded, medium-dark gray and dark-greenish gray shales, siltstones, and sandstones crop out for a distance of 450 feet along the roadway in beds one to three inches thick. The rocks are relatively unweathered and difficult to break. Fragments are platy to tabular in shape and range from one inch to more than one foot in length. The smaller, platy fragments are generally shale. The outcrop is 40 feet high.

Attitude of Bedding: N65E, 25S; Cleavage-bedding relationship in the shale indicates the beds are right side up with the crest of anticline to the north.

Sampled Interval: Composite sample of material representative of the sequence of beds in the outcrop.

Type of Material: Shale, siltstone, and sandstone

Ceramic Testing Laboratory: Norris

Chemical Analysis:

Analyst: Spectrochemical	%
L.O.I. @ 1,000°C	7.39
H_2O Loss @ 110°C	0.18
Combined H_2O	NA
SiO_2	67.90
Al_2O_3	6.60
Fe_2O_3	3.09
FeO	2.57

Mineralogy (X-ray):

	%	Accuracy (±%)
Quartz	36	6
Mica	30	7
Kaolinite	14	8
C-V-Mo	6	3
Feldspar	8	3

Remarks: Mineralogy indicates chemical analysis is low in Al_2O_3

Chemical Analysis:

Analyst: Spectrochemical %

CaO	6.95
MgO	1.34
CO_2	3.82
Na_2O	1.33
K_2O	2.20
TiO_2	0.53
P_2O_5	NA
MnO	NA
S (total)	< 0.02
C (total)	0.69

Other Properties:

pH: 8.30
P.C.E.: NA
Water of Plasticity (%): 17.0
Drying Shrinkage (%): 0.0
Dry Strength: Poor
Drying Characteristics: Fair; scum; warping
Workability: Mealy; gritty; short-working

Slow-Firing Tests:

Temp. °F	*Color*	*Hardness*	*% Shk.*	*% Absorb.*	*% App. Por.*	*Approx. Sp. Gr.*
1800	Dull tan	Fair hard	0.0	4.7	—	2.52
1900	Dull tan	Fair hard	0.0	5.3	—	2.45
2000	Dull tan	Fair hard	0.0	5.8	—	2.40
2100	Light brown	Hard	0.0	9.3	—	2.33
2200	Very dark brown	Very hard	0.0	126.7	—	1.73
2300						

Pyrometric cone equivalent: NA **Bloating test:** Positive

Remarks: Bloats at 2150°F; poor color; scum; warping

Bloating Tests (Quick-Firing):

Crushing characteristics Good Particle size: —¾″ + ½″
Drying characteristics Good Retention time: 15 minutes

Temp. °F	*Bulk Density*	*Lb/Ft³*	*% Absorb.*	*Remarks*
1800	—	—		
1900	2.73	170	10.2	No expansion
2000	2.28	142	21.8	Slight expansion
2100	1.40	87	12.8	Fair expansion, fair skin
2200				
2300				

Recommendations: Would make a slightly heavy lightweight aggregate.

Other Tests: Soluble Br. K. 1.10

Potential Uses: Quick-firing bloating tests suggest this raw material would make a slightly heavy lightweight aggregate.

BERKS COUNTY Windsor Twp.

Sample Number
186-7-10

Quadrangle: Hamburg 15′; Hamburg 7½′

Location: Road cut on the south side of U. S. Route 22, 0.9 mile east of Edenburg, Pa. or 600 feet east of St. Paul's Church.

Geologic Unit: Martinsburg Formation, Ordovician

Description: Greenish-gray (5 G 5/1) shale which weathers to grayish-orange is exposed in a roadcut 600 feet long and 12 feet high.

Attitude of Bedding: Not measured

Sampled Interval: Grab sample of exposure

Type of Material: Shale

Ceramic Testing Laboratory: Tuscaloosa

Chemical Analysis:

Analyst: Conwell	%
L.O.I. @ 1,000°C	5.37
H_2O Loss @ 110°C	0.58
Combined H_2O	5.92
SiO_2	59.10
Al_2O_3	18.74
Fe_2O_3	4.94
FeO	2.81
CaO	0.10
MgO	2.58
CO_2	0.10
Na_2O	0.52
K_2O	3.72
TiO_2	0.82
P_2O_5	NA
MnO	NA
S (total)	None
C (total)	0.42

Mineralogy (X-ray):

	%	Accuracy (±%)
Quartz	27	5
Mica	45	6
Kaolinite	10	7
C-V-Mo	12	3
Feldspar	1	1

Remarks:

Other Properties:

pH: 6.70
P.C.E.: NA
Water of Plasticity (%): 16.0
Drying Shrinkage (%): 2.5
Dry Strength: Low
Drying Characteristics: No defects
Workability: Low plasticity

Slow-Firing Tests:

Temp. °F	*Color*	*Hardness*	*% Shk.*	*% Absorb.*	*% App. Por.*	*Approx. Sp. Gr.*
1800	Tan	Moh's 2	2.5	13.7	26.6	1.94
1900	Light brown	Moh's 2	5.0	9.9	20.7	2.09
2000	Brown	Moh's 3	5.0	6.8	15.1	2.22
2100	Red-brown	Moh's 4	7.5	1.4	3.4	2.41
2200	Expanded	—	—	—	—	—

Pyrometric cone equivalent: NA **Bloating test:** Negative

Remarks: Poor color

Bloating Tests (Quick-Firing): NA

Other Tests: Not effervescent with HCl

Potential Uses: Should fire to "SW" face brick specifications at about 1950°F.

BERKS COUNTY Greenwich Twp.

Sample Number
186-9-9

Quadrangle: Hamburg 15'; Kutztown 7½'

Location: Roadcut 0.8 mile west of Krumsville, Pa., on the south side of U. S. Route 22.

Geologic Unit: Martinsburg Formation, Ordovician

Description: Medium-olive gray (5 Y 5/1) shale with minor siltstone is exposed in the roadcut. With weathering the shale changes to light-yellowish brown (10 YR 6/4) becoming reddish toward the western end of the exposure. The red phase was not sampled. At the eastern end of the outcrop, the shale becomes sandy.

Attitude of Bedding: Not measured

Sampled Interval: Composite sample

Type of Material: Shale

Ceramic Testing Laboratory: Tuscaloosa

Chemical Analysis:

Analyst: Conwell	%
L.O.I. @ 1,000°C	4.67
H_2O Loss @ 110°C	0.56
Combined H_2O	5.04
SiO_2	60.26
Al_2O_3	18.77
Fe_2O_3	4.57
FeO	2.38
CaO	0.40
MgO	2.40
CO_2	0.20
Na_2O	1.03
K_2O	3.20
TiO_2	0.86
P_2O_5	NA
MnO	NA
S (total)	None
C (total)	0.29

Mineralogy (X-ray):

	%	Accuracy (±%)
Quartz	27	6
Mica	46	8
Kaolinite	7	7
C-V-Mo	13	3
Feldspar	2	1

Remarks:

Other Properties:

pH: 7.80
P.C.E.: NA
Water of Plasticity (%): 16.0
Drying Shrinkage (%): 2.50
Dry Strength: Low
Drying Characteristics: No defect
Workability: Low plasticity

Temp. °F	*Color*	*Hardness*	*% Shk.*	*% Absorb.*	*% App. Por.*	*Approx. Sp. Gr.*
1800	Tan	Moh's 2	2.5	14.1	27.2	1.93
1900	Light brown	Moh's 2	2.5	12.6	25.2	2.00
2000	Brown	Moh's 3	5.0	7.4	16.1	2.18
2100	Red-brown	Moh's 4	7.5	2.0	4.8	2.38
2200	Expanded	—	—	—	—	—

Pyrometric cone equivalent: NA **Bloating test:** Negative

Remarks: Poor color

Bloating Tests (Quick-Firing): NA

Other Tests: Not effervescent with HCl

Potential Uses: Should fire to "SW" face brick specifications at about 2000°F.

BERKS COUNTY **Robeson Twp.**

Sample Number
188-1-3

Quadrangle: Honeybrook 15′; Morgantown 7½′

Location: Road cut along the west side of Interstate Route 176, about 3.5 miles north-northwest of Morgantown, Pa.

Geologic Unit: Brunswick Formation, Triassic

Description: Predominantly pale-reddish brown, thin-bedded slightly weathered shales are interbedded with siltstone and massive sandstone beds. The shale beds constitute about 65 percent of the outcrop which is about 680 feet long. Shale fragments are platy to tabular in shape with irregular edges and range from one to four inches in length.

Attitude of Bedding: N40W, 15N

Sampled Interval: Channel sample of 20 stratigraphic feet of shale.

Type of Material: Shale

Ceramic Testing Laboratory: Norris

Chemical Analysis:

Analyst: Spectrochemical %

L.O.I. @ 1,000°C	3.83
H_2O Loss @ 110°C	1.24
Combined H_2O	NA
SiO_2	71.00
Al_2O_3	12.40
Fe_2O_3	6.19
FeO	0.27
CaO	0.42
MgO	0.98
CO_2	0.15
Na_2O	0.62
K_2O	3.38
TiO_2	0.86
P_2O_5	NA
MnO	NA
S (total)	$>$ 0.03
C (total)	0.14

Mineralogy (X-ray):

	%	*Accuracy* (±%)
Quartz	40	7
Mica	42	6
Kaolinite	0	—
C-V-Mo	7	3
Feldspar	1	1

Remarks: Mineralogy indicates chemical analysis is low in Al_2O_3.

Other Properties:

pH: 7.90
P.C.E.: NA
Water of Plasticity (%): 19.8
Drying Shrinkage (%): 2.5
Dry Strength: Good
Drying Characteristics: Good; scum
Workability: Plastic; smooth; short-working

Slow-Firing Tests:

Temp. °F	*Color*	*Hardness*	*% Shk.*	*% Absorb.*	*% App. Por.*	*Approx. Sp. Gr.*
1800	Light tan	Fair hard	3.0	5.7	—	2.20
1900	Tan	Hard	4.0	6.9	—	2.19
2000	Light brown	Very hard	5.0	13.2	—	2.19
2100	Chocolate	Very hard	9.0	23.1	—	2.14
2200	Dark brown	Steel hard	9.0	30.5	—	2.01
2300						

Pyrometric cone equivalent: NA **Bloating test:** Negative

Remarks: Fair color; scum; high absorption; wavy surface. Addition of barium salts would control scum.

Bloating Tests (Quick-Firing): NA

Other Tests: Soluble Br. K. 0.70

Potential Uses: NW Grade face brick

BERKS COUNTY Robeson Twp.

Sample Number
188-2-2

Quadrangle: Honeybrook 15′; Elverson 7½′

Location: Exposure along the Reading Railroad Co. tracks about 550 feet southwest of the railroad crossing on Pa. Route 82 near Joanna Heights, Pa.

Geologic Unit: Stockton Formation, Triassic

Description: Interbedded grayish red and pale red-brown shales and sandstones are exposed in the southwestern 350 feet of a 550 foot-long railroad cut. The sample represents only the thin-bedded shales which are 30 feet thick in the southwestern part of the railroad cut. The northeastern 200 feet of the exposure is sandstone.

Attitude of Bedding: N75W, 24N

Sampled Interval: Channel sample of 30 stratigraphic feet of shale

Type of Material: Shale

Ceramic Testing Laboratory: Tuscaloosa

Chemical Analysis:

Analyst: Spectrochemical %

L.O.I. @ 1,000°C	3.57
H_2O Loss @ 110°C	1.23
Combined H_2O	NA
SiO_2	70.30
Al_2O_3	13.00
Fe_2O_3	6.20
FeO	0.40
CaO	0.12
MgO	1.04
CO_2	0.29
Na_2O	0.62
K_2O	3.80
TiO_2	0.93
P_2O_5	NA
MnO	NA
S (total)	$>$ 0.20
C (total)	0.14

Mineralogy (X-ray):

	%	*Accuracy (±%)*
Quartz	40	6
Mica	40	6
Kaolinite	9	5
C-V-Mo	0	—
Feldspar	1	1

Remarks: Mineralogy indicates chemical analysis is low in Al_2O_3.

Other Properties:

pH: 6.70
P.C.E.: NA
Water of Plasticity (%): 21.2
Drying Shrinkage (%): 2.5
Dry Strength: Good
Drying Characteristics: Good; slight scum
Workability: Plastic; smooth, short-working

Slow-Firing Tests:

Temp. °F	Color	Hardness	% Shk.	% Absorb.	% App. Por.	Approx. Sp. Gr.
1800	Tan	Fair hard	3.0	4.5	—	2.15
1900	Tan	Fair hard	3.5	5.3	—	2.17
2000	Light brown	Hard	5.0	6.7	—	2.15
2100	Chocolate	Very hard	10.0	12.3	—	2.12
2200	Dark brown	Steel hard	10.0	22.8	—	2.03
2300	Black	Melted	—	—	—	—

Pyrometric cone equivalent: NA **Bloating test:** Negative

Remarks: Fair color; slight crazing; layered cracks; scum; high absorption. Addition of barium salts would remove scum.

Bloating Tests (Quick-Firing): NA

Other Tests: Soluble Br. K. 0.35

Potential Uses: NW Grade face brick

BERKS COUNTY Douglass Twp.

Sample Number
197-7-2

Quadrangle: Boyertown 15′; Boyertown 7½′

Location: Outcrop about 1.3 miles east-southeast of Douglassville, Pa., and northeast of the intersection of U.S. Route 422 and a medium-duty road leading northeast toward the Pottstown Traprock Quarries (marked on the topographic map as a gravel pit).

Geologic Unit: Brunswick Formation, Triassic.

Description: Grayish red, slightly calcareous, thin- to massive-bedded shale is exposed for a distance of 200 feet along the road. The majority of the shale beds are one to six inches thick and weather to tabular-shaped fragments. Some of the fractures are quartz-filled. The height of the outcrop is 18 feet.

Attitude of Bedding: N85W, 40N

Sampled Interval: Channel sample of 10 stratigraphic feet collected from the north end of the outcrop.

Type of Material: Shale

Ceramic Testing Laboratory: Norris

Chemical Analysis:

Analyst: McCreath

	%
L.O.I. @ 1,000°C	NA
H_2O Loss @ 110°C	NA
Combined H_2O	4.49
SiO_2	53.95
Al_2O_3	16.77
Fe_2O_3	8.48
FeO	0.32
CaO	2.69
MgO	2.67

Mineralogy (X-ray):

	%	Accuracy (±%)
Quartz	25	5
Mica	38	6
Kaolinite	8	6
C-V-Mo	9	3
Feldspar	11	3

Remarks:

Chemical Analysis:

Analyst: McCreath

	%
CO_2	1.95
Na_2O	1.47
K_2O	3.81
TiO_2	0.98
P_2O_5	NA
MnO	NA
S (total)	< 0.01
C (total)	0.05

Other Properties:

pH: 9.40
P.C.E.: NA
Water of Plasticity (%): 22.0
Drying Shrinkage (%): 2.0
Dry Strength: Good
Drying Characteristics: Good, slight warping
Workability: Short working, smooth, fatty

Slow-Firing Tests:

Temp. °F	*Color*	*Hardness*	*% Shk.*	*% Absorb.*	*% App. Por.*	*Approx. Sp. Gr.*
1800	Lt. red brown	Fair hard	2.0	5.2	—	2.61
1900	Lt. red brown	Hard	3.5	5.4	—	2.58
2000	Brown	Very hard	6.0	8.3	—	2.44
2100	Very dark brown	Very hard	14.5	30.5	—	2.26
2200	Melted	—	—	—	—	—
2300						

Pyrometric cone equivalent: NA **Bloating test:** Positive

Remarks: Poor color, slight scum, short firing range

Bloating Tests (Quick-Firing):

Crushing characteristics: Good Particle size: —¾" + ½"
Drying characteristics: Good Retention time:

Temp. °F	*Bulk Density*	*Lb/Ft³*	*% Absorb.*	*Remarks*
1800	—	—	—	
1900	2.52	157	2.0	No expansion
2000	1.75	110	2.0	Slight expansion
2100	1.31	72	5.7	Good expansion—cracks
2200				Melted
2300				

Recommendations: Fair lightweight aggregate possibility.

ROTARY KILN TESTS

Raw Material:

Screen Analysis (Crushed through a hammermill with 1½" screen)

Size		*Percent Retained*
—¾"	+ ½"	34.6
—½"	+ ⅜"	18.3
—⅜"	+ 4 mesh	25.9
—4 mesh	+ 8 mesh	5.7
—8 mesh	PAN	15.5
	TOTAL	100.0

Crushing loss (—4 mesh) 21.2%

Fragment shape: Angular

Firing Data:

Size range of feed: —¾ + 4 mesh Pour weight of feed: 85.0 lb/ft^3

Bloating temperature: 2040°F

Logging temperature* (*Nodules sticking together): 2060°F

Fired Material (all fired material crushed through a roll crusher)

Screen Analysis* (*ASTM Designation C 311-59T) in percentages by weight passing sieves:

Size designation	¾″	½″	⅜″	No. 4	No. 8	No. 16	No. 50	No. 100
Fine	—	—	100.0	64.0	—	26.4	10.2	6.6
Coarse	100.0	59.0	27.0	15.0	10.5	—	—	—

Loose pour weight* (*ASTM Designation C 311-59T):

Fine: 65.0 lb/ft^3 Coarse: 57.5 lb/ft^3

Color: Dark brown

COMMENTS: Not promising for lightweight aggregate; too heavy. Angular fragments; fine pores; fair crushing.

Other Tests: Soluble Br. K. 0.53

Potential Uses: Regular brick, if color improved; rotary kiln tests indicate it is not a promising raw material for lightweight aggregate use.

BUCKS COUNTY Nockamixon Twp.

Sample Number
216-8-1

Quadrangle: Easton 15′; Riegelsville 7½′

Location: Outcrop on the south side of Pa. Route 32, about 1.75 miles northeast of Kintnersville, Pa.

Geologic Unit: Brunswick Formation, Triassic.

Description: Grayish red, slightly calcareous, wavy- to irregularly-bedded, massive, shale crops out for a considerable distance along the roadway. The slightly to moderately weathered shale, in beds up to six feet thick, is moderately resistant to breakage and breaks with a hackly fracture. Some of the beds exhibit thin, irregular fractures parallel to bedding.

Attitude of Bedding: N-S, 15W

Sampled Interval: Composite sample of approximately 20 stratigraphic feet.

Type of Material: Shale

Ceramic Testing Laboratory: Tuscaloosa

Chemical Analysis:

Analyst: Conwell	%
L.O.I @ 1,000°C	6.24
H_2O Loss @ 110°C	0.25
Combined H_2O	2.20
SiO_2	54.56
Al_2O_3	17.49
Fe_2O_3	5.59
FeO	1.15
CaO	3.53
MgO	3.07
CO_2	4.00
Na_2O	2.62
K_2O	3.12
TiO_2	0.80
P_2O_5	NA
MnO	NA
S (total)	None
C (total)	0.05

Mineralogy (X-ray):

	%	Accuracy (±%)
Quartz	20	5
Mica	35	7
Kaolinite	15	7
C-V-Mo	0	—
Feldspar	15	3

Remarks: Carbonate present

Other Properties:

pH: 6.70
P.C.E.: NA
Water of Plasticity (%): 16.7
Drying Shrinkage (%): 0.0
Dry Strength: Low
Drying Characteristics: No defects
Workability: Low plasticity

Slow-Firing Tests:

Temp. °F	Color	Hardness	% Shk.	% Absorb.	% App. Por.	Approx. Sp. Gr.
1800	Light brown	Moh's 2	0.0	19.2	33.6	1.75
1900	Light brown	Moh's 2	0.0	19.7	33.9	1.72
2000	Brown	Moh's 2	0.0	16.3	28.2	1.73
2100	Expanded	—	—	—	—	—
2200						
2300						

Pyrometric cone equivalent: NA **Bloating test:** Negative

Remarks: Abrupt vitrification; may be limy.

Bloating Tests (Quick-Firing): NA

Other Tests: Highly effervescent in HCl.

Potential Uses: No designated ceramic use.

BUCKS COUNTY Tinicum Twp.

Sample Number
216-9-2

Quadrangle: Easton 15′; Frenchtown 7½′

Location: Abandoned quarry about 0.3 mile north of Uhlerstown, Pa., on the west side of the unpaved road between Jugtown and Uhlerstown, Pa.

Geologic Unit: Brunswick Formation, Triassic.

Description: Grayish red, slightly to moderately weathered, medium-bedded shales with tiny flakes of mica scattered throughout the rock are exposed in beds averaging 6 inches in thickness. Some weathered units exhibit a platy structure parallel to bedding. The shale is moderately hard, and fragments at the base of the quarry are tabular to platy in shape. The quarry is 50 x 500 x 50 feet.

Attitude of Bedding: N-S, 5W

Sampled Interval: Composite sample of 15 stratigraphic feet.

Type of Material: Shale

Ceramic Testing Laboratory: Tuscaloosa

Chemical Analysis:

Analyst: Conwell	%
L.O.I. @ 1,000°C	3.19
H_2O Loss @ 110°C	0.37
Combined H_2O	2.83
SiO_2	59.78
Al_2O_3	19.49
Fe_2O_3	3.20
FeO	4.39
CaO	0.76
MgO	2.11
CO_2	0.36
Na_2O	2.30
K_2O	3.05
TiO_2	0.85
P_2O_5	NA
MnO	NA
S (total)	None
C (total)	0.00

Mineralogy (X-ray):

	%	Accuracy (±%)
Quartz	21	5
Mica	46	6
Kaolinite	10	6
C-V-Mo	6	3
Feldspar	12	3

Remarks:

Other Properties:

pH: 8.00
P.C.E.: NA
Water of Plasticity (%): 21.2
Drying Shrinkage (%) 2.5
Dry Strength: Low
Drying Characteristics: No drying defects
Workability: Low plasticity

Slow-Firing Tests:

Temp. °F	*Color*	*Hardness*	*% Shk.*	*% Absorb.*	*% App. Por.*	*Approx. Sp. Gr.*
1800	Tan	Moh's 3	2.5	15.3	—	1.82
1900	Tan	Moh's 4	5.0	11.3	—	1.94
2000	Red brown	Moh's 5	12.5	1.2	—	2.35
2100	Expanded	—	—	—	—	—
2200						
2300						

Pyrometric cone equivalent: NA **Bloating test:** Negative

Remarks: Short vitrification range.

Bloating Tests (Quick Firing): NA

Other Tests: Highly effervescent.

Potential Uses: No designated ceramic material.

Remarks: The quarry is presently being operated for road fill material.

BUCKS COUNTY Bedminster Twp.

Sample Number
217-2-4

Quadrangle: Doylestown 15′; Bedminster 7½′

Location: Exposure on the west side of U.S. Route 611, about 0.3 mile northwest of Pipersville, Pa.

Geologic Unit: Lockatong Formation, Triassic.

Description: A sequence of thin- to thick-bedded (0.5 inch to two feet), locally calcareous, shale and argillite is exposed midway between Philadelphia Electric Company poles 17803 and 17804. The rock breaks with a conchoidal to irregular fracture; the argillite is more resistant to breakage. Most of the rock is medium-dark gray to dark gray; however, the lowermost 1.5 feet of the section sampled is olive green. Pyrite is scattered throughout the dark gray shale and argillite.

Attitude of Bedding: N45E, 10N

Sampled Interval: Composite sample of 8 stratigraphic feet of section collected along 1,000 feet of exposure.

Type of Material: Shale and argillite

Ceramic Testing Laboratory: Norris

Chemical Analysis:

Analyst: Spectrochemical	%
L.O.I. @ 1,000°C	4.15
H_2O Loss @ 110°C	0.17
Combined H_2O	NA
SiO_2	61.90
Al_2O_3	13.30
Fe_2O_3	3.89
FeO	3.99
CaO	1.92
MgO	2.02
CO_2	1.10
Na_2O	4.66
K_2O	3.00
TiO_2	0.78
P_2O_5	NA
MnO	NA
S (total)	< 0.06
C (total)	0.35

Mineralogy (X-ray):

	%	*Accuracy (±%)*
Quartz	21	7
Mica	29	7
Kaolinite	13	9
C-V-Mo	12	3
Feldspar	20	4

Remarks: Mineralogy indicates chemical analysis is low in Al_2O_3.

Other Properties:

pH: 8.00
P.C.E.: NA
Water of Plasticity (%): 21.0
Drying Shrinkage (%): 2.0
Dry Strength: Fair
Drying Characteristics: Fair; crazing; slight warping; scum
Workability: Fatty; smooth; short-working

Slow-Firing Tests:

Temp. °F	*Color*	*Hardness*	*% Shk.*	*% Absorb.*	*% App. Por.*	*Approx. Sp. Gr.*
1800	Tan	Soft	4.0	5.1	—	2.63
1900	Tan	Fair hard	4.0	5.1	—	2.61
2000	Light brown	Hard	4.0	10.7	—	2.41
2100	Brown	Very hard	9.0	35.6	—	2.23
2200	Melted	—	—	—	—	—
2300						

Pyrometric cone equivalent: NA **Bloating test:** Positive

Remarks: Poor color; color uneven; crazing; warping; very high absorption; melts at 2150°F; scum. No ceramic uses.

Bloating Tests (Quick-Firing):

Crushing characteristics	Good	Particle size	—¾" + ½"
Drying characteristics	Good	Retention time	15 mintues

Temp. °F	*Bulk Density*	*Lb/Ft³*	*% Absorb.*	*Remarks*
1800	—	—	—	
1900	2.44	152	26.5	No expansion
2000	1.67	104	16.7	Slight expansion, fair skin
2100	0.66	41	10.9	Fine expansion, good skin
2200				Melted
2300				

Recommendations: Fine lightweight aggregate possibilities.

Other Tests: Soluble Br. K. 1.00
Slightly effervescent (carbonate)

Potential Uses: Quick-firing bloating tests indicate this raw material might make a fine lightweight aggregate.

Remarks: See Samples 217-2-4A, B and C. Slow-firing test indicates that this material has no use as ceramic raw material.

BUCKS COUNTY Bedminster Twp.

Sample Number
217-2-4A

Quadrangle: Doylestown 15′; Bedminster 7½′

Location: Exposure on the west side of U.S. Route 611, about 0.3 mile northwest of Pipersville, Pa.

Geologic Unit: Brunswick Formation, Triassic.

Description: Massive-appearing, grayish red (5 R 4/2) argillite beds are exposed in the northern part of the road cut. Some of the massive beds, ranging up to 2.5 feet in thickness, have a platy character when weathered. The rock fragments are commonly platy with irregular, sharp edges and 2 to 3 inches in length. The argillite is locally calcareous.

Attitude of Bedding: N45E, 10N

Sampled Interval: Composite sample of 6 stratigraphic feet.

Type of Material: Argillite

Ceramic Testing Laboratory: Norris

Chemical Analysis:

Analyst: Spectrochemical %

L.O.I. @ 1,000°C	3.04
H_2O Loss @ 110°C	0.22
Combined H_2O	NA
SiO_2	64.50
Al_2O_3	13.25
Fe_2O_3	6.51
FeO	1.13
CaO	0.15
MgO	1.70
CO_2	0.58
Na_2O	4.77
K_2O	4.10
TiO_2	0.75
P_2O_5	NA
MnO	NA
S (total)	$>$ 0.03
C (total)	0.19

Mineralogy (X-ray):

	%	Accuracy (±%)
Quartz	21	6
Mica	37	7
Kaolinite	6	8
C-V-Mo	10	3
Feldspar	16	3

Remarks:

Other Properties:

pH: 8.30
P.C.E.: NA
Water of Plasticity (%): 20.0
Drying Shrinkage (%): 3.0
Dry Strength: Fair
Drying Characteristics: Fair; warping; scum
Workability: Gritty; smooth; fatty; short-working

Slow-Firing Tests:

Temp. °F	*Color*	*Hardness*	*% Shk.*	*% Absorb.*	*% App. Por.*	*Approx. Sp. Gr.*
1800	Red brown	Fair hard	5.0	6.3	—	2.66
1900	Red brown	Fair hard	5.0	5.5	—	2.64
2000	Red brown	Hard	5.0	1.19	—	2.51
2100	Very dk. brown	Partially Melted	—	—	—	—
2200	Melted	—	—	—	—	—
2300	Melted	—	—	—	—	—

Pyrometric cone equivalent: NA **Bloating test:** Negative

Remarks: Poor color, scum, too soft, warped.

Bloating Tests (Quick-Firing): NA

Other Tests: Soluble Br. K. 1.10

Potential Uses: No designated ceramic use.

Remarks: See also Samples 217-2-4; 217-2-4B; 217-2-4C. Samples 217-2-4A, 217-2-4B, and 217-2-4C were collected as a single bulk sample for rotary kiln tests. See Sample 217-2-4B for test results.

BUCKS COUNTY Bedminster Twp.

Sample Number
217-2-4B

Quadrangle: Doylestown 15′; Bedminster 7½′

Location: Exposure along the west side of U. S. Route 611, about 0.3 mile northwest of Pipersville, Pa.

Geologic Unit: Lockatong Formation, Triassic

Description: A series of thin-bedded, medium-dark gray to dark gray shale beds are exposed at the south end of the roadcut, stratigraphically overlying a dark gray pyritic shale. The shale beds range from 0.5 to three inches in thickness and break into small platy- to tabular-shaped fragments with sharp irregular edges. Microscopic examination shows the presence of minute flakes of muscovite and a few quartz sand grains scattered throughout the matrix. The unit sampled measures 40 stratigraphic inches.

Attitude of Bedding: N25E, 8N

Sampled Interval: Composite sample of 40 stratigraphic inches.

Type of Material: Shale

Ceramic Testing Laboratory: Norris

Chemical Analysis:

Analyst: Spectrochemical	%
L.O.I. @ 1,000°C	4.12
H_2O Loss @ 110°C	0.41
Combined H_2O	NA
SiO_2	63.40
Al_2O_3	14.20
Fe_2O_3	4.21
FeO	3.51
CaO	0.08
MgO	2.83
CO_2	NA
Na_2O	1.98
K_2O	4.95
TiO_2	0.68
P_2O_5	NA
MnO	NA
S (total)	< 0.06
C (total)	0.21

Mineralogy (X-ray):

	%	Accuracy (±%)
Quartz	26	8
Mica	48	10
Kaolinite	6	4
C-V-Mo	11	4
Feldspar	2	1

Remarks: Mineralogy indicates chemical analysis is low in Al_2O_3.

Other Properties:

pH: 7.90
P.C.E.: NA
Water of Plasticity (%): 21.0
Drying Shrinkage (%): 5.0
Dry Strength: Fair
Drying Characteristics: Good, slight warping
Workability: Slightly gritty; fatty; short-working

Slow-Firing Tests:

Temp. °F	*Color*	*Hardness*	*% Shk.*	*% Absorb.*	*% App. Por.*	*Approx. Sp. Gr.*
1800	Tan	Fair hard	5.0	5.6	—	2.67
1900	Tan	Fair hard	5.0	6.8	—	2.63
2000	Brown	Hard	10.0	24.7	—	2.42
2100	Very dark brown	Very hard—Surface glassy	—	—	—	—
2200	Melted	—	—	—	—	—
2300	Melted	—	—	—	—	—

Pyrometric cone equivalent: NA **Bloating test:** Positive

Remarks: Poor color, dull, too soft.

Bloating Tests (Quick-Firing):

Crushing characteristics: Fair; fines — Particle size: —¾" + ½"
Drying characteristics: Good — Retention time: 15 minutes

Temp. °F	*Bulk Density*	*Lb/Ft³*	*% Absorb.*	*Remarks*
1800	—			
1900	2.00	127	14.6	No expansion
2000	0.75	46	6.9	Fine expansion, cracks
2100	0.63	39	6.6	Fine expansion, overfired
2200				Melted
2300				

Recommendations: Fine lightweight aggregate possibilities, but because of short bloating range there is need of controlled firing.

ROTARY KILN TESTS:

Raw Material:

Screen Analysis (Crushed through a hammermill with 1½" screen)

Size		*Percent Retained*
—¾"	+ ½"	29.9
—½"	+ ⅜"	17.1
—⅜"	+ 4 mesh	22.5
—4 mesh	+ 8 mesh	5.5
—8 mesh	PAN	25.0
	TOTAL	100.0

Crushing loss (—4 mesh) 30.5%

Fragment shape: Angular

Firing Data:

Size range of feed: —¾ + 4 mesh — Pour weight of feed: 80.0 lb/ft³

Bloating temperature: 2020°F

Logging temperature* (*Nodules sticking together): 2050°F

Fired Material (all fired material crushed through a roll crusher)

Screen Analysis* (*ASTM Designation C 311-59T) in percentages by weight passing sieves:

Size designation	¾"	½"	⅜"	No. 4	No. 8	No. 16	No. 50	No. 100
Fine	—	—	100.0	62.0	—	23.0	10.6	7.7
Coarse	100.0	64.0	28.0	5.0	4.0	—	—	—

Loose pour weight* (*ASTM Designation C 211-59T):

Fine: 57.5 lb/ft³ — Coarse: 55.0 lb/ft³

Color: Dark brown

COMMENTS: Not promising for lightweight aggregate. Some non-bloating material; angular fragments; fine pore structure; good crushing.

Other Tests: Soluble Br. K. 0.80

Potential Uses: No designated ceramic use.

Remarks: See also Samples 217-2-4, 217-2-4A, and 217-2-4C. Samples 217-2-4A, 217-2-4B, and 217-2-4C were collected as one bulk sample for rotary kiln tests. Results of rotary kiln tests accompany testing results for this sample. Sample 217-2-4B, is not repeated under data for Sample 217-2-4A or Sample 217-2-4C.

BUCKS COUNTY Bedminster Twp.

Sample Number
217-2-4C

Quadrangle: Doylestown 15′; Bedminster 7½′

Location: Exposure along the west side of U. S. Route 611, about 0.3 mile northwest of Pipersville, Pa.

Geologic Unit: Lockatong Formation, Triassic

Description: Medium-dark gray to dark gray, slightly calcareous, fissile shale grading upward into thin-bedded shale stratigraphically overlies Sample 217-2-4B. One bed within the sample interval contains a minor amount of pyrite.

Attitude of Bedding: N25E, 8N

Sampled Interval: Composite sample of 5 stratigraphic feet.

Type of Material: Shale

Ceramic Testing Laboratory: Norris

Chemical Analysis:

Analyst: Spectrochemical	%
L.O.I. @ 1,000°C	5.83
H_2O Loss @ 110°C	0.31
Combined H_2O	NA
SiO_2	62.60
Al_2O_3	13.50
Fe_2O_3	4.26
FeO	1.74
CaO	1.60
MgO	1.69
CO_2	1.62
Na_2O	4.27
K_2O	3.80
TiO_2	0.69
P_2O_5	NA
MnO	NA
S (total)	0.12
C (total)	1.85

Mineralogy (X-ray):

	%	Accuracy (±%)
Quartz	23	7
Mica	20	8
Kaolinite	7	5
C-V-Mo	11	3
Feldspar	28	4

Remarks: Mineralogy indicates chemical analysis is low in Al_2O_3. Carbonates present.

Other Properties:

pH: 7.40
P.C.E.: NA
Water of Plasticity (%): 22.0
Drying Shrinkage (%): 5.0
Dry Strength: Good
Drying Characteristics: Good; slight warping; slight scum
Workability: Fatty; short-working

Slow-Firing Tests:

Temp. °F	Color	Hardness	% Shk.	% Absorb.	% App. Por.	Approx. Sp. Gr.
1800	Tan	Soft	5.0	4.0	—	2.61
1900	Tan	Soft	5.0	3.9	—	2.60
2000	Tan	Fair hard	5.0	6.2	—	1.98
2100	Very dark brown—glassy—slight expansion					
2200	Melted	—	—	—	—	—
2300	Melted	—	—	—	—	—

Pyrometric cone equivalent: NA **Bloating test:** Positive

Remarks: Poor color; scum; too soft; expands.

Bloating Tests (Quick-Firing):
Crushing characteristics: NA Particle size: NA
Drying characteristics: NA Retention time: 15 minutes

Temp. °F	Bulk Density	Lb/Ft^3	% Absorb.	Remarks
1800	—	—	—	
1900	2.35	146	12.5	No expansion
2000	1.25	77	10.6	Fair expansion, good skin
2100				Melted
2200				(Short bloating range)
2300				

Recommendations: Fair lightweight aggregate possibilities.

Other Tests: Soluble Br. K. 2.30. Slightly effervescent with HCl.

Potential Uses: No designated ceramic use.

Remarks: See Samples 217-2-4, 217-2-4A, 217-2-4B. Slow firing test suggests material not suitable for the general ceramic uses. Sample 217-2-4A, 217-2-4B, and 217-2-4C were collected as one bulk sample for rotary kiln tests; see Sample 217-2-4B for test results.

BUCKS COUNTY Bedminster Twp.

Sample Number
217-2-5

Quadrangle: Doylestown 15′; Bedminster 7½′

Location: Abandoned quarry in the northwest quadrant of the intersection of a medium-duty road with U. S. Route 611. The quarry is about 0.75 mile north-northwest of Pipersville, Pa.

Geologic Unit: Brunswick Formation, Triassic

Description: Grayish red (5 R 4/2), slightly calcareous and containing disseminated mica (Muscovite?), thick-bedded shales (up to 14 inches thick) were sampled from rock exposed in the south wall of the quarry. The weathered shale exhibits a finely laminar structure and the corners of joint blocks tend to be round. The basal 6 stratigraphic feet of the shale exposed in the quarry were sampled as a unit.

Attitude of Bedding: N60E, 10N

Sampled Interval: Composite sample of the lower 6 stratigraphic feet of section.

Type of Material: Shale

Ceramic Testing Laboratory: Norris

Chemical Analysis:

Analyst: Spectrochemical

	%
L.O.I. @ 1,000°C	3.30
H_2O Loss @ 110°	0.28
Combined H_2O	NA
SiO_2	62.30
Al_2O_3	14.00
Fe_2O_3	7.80
FeO	0.64
CaO	1.24
MgO	2.04
CO_2	0.51
Na_2O	3.70
K_2O	4.20
TiO_2	0.77
P_2O_5	NA
MnO	NA
S (total)	> 0.01
C (total)	0.14

Mineralogy (X-ray):

	%	Accuracy (±%)
Quartz	19	10
Mica	38	10
Kaolinite	0	—
C-V-Mo	11	3
Feldspar	23	4

Remarks: Mineralogy indicates chemical analysis is low in Al_2O_3.

Other Properties:

pH: 8.20
P.C.E.: NA
Water of Plasticity (%): 22.0
Drying Shrinkage (%): 5.0
Dry Strength: Fair
Drying Characteristics: Good; slightly wavy
Workability: Gritty; smooth; fatty; short-working

Slow-Firing Tests:

Temp. °F	Color	Hardness	% Shk.	% Absorb.	% App. Por.	Approx. Sp. Gr.
1800	Lt. red brown	Fair hard	6.0	5.6	—	2.64
1900	Lt. red brown	Fair hard	6.0	6.1	—	2.61
2000	Brown	Hard	9.0	15.3	—	2.47
2100	Very dark brown	Very hard-glassy-expanded				
2200	Melted	—	—	—	—	—
2300	Melted	—	—	—	—	—

Pyrometric cone equivalent: NA **Bloating test:** Negative

Remarks: Poor color; too soft; slight scum.

Bloating Tests (Quick-Firing): NA

Other Tests: Soluble Br. K. 1.10. Effervescent (carbonate)

Potential Uses: No designated ceramic use

Remarks: See Sample 217-2-5A

BUCKS COUNTY Bedminster Twp.

Sample Number
217-2-5A

Quadrangle: Doylestown 15′; Bedminster 7½′

Location: Abandoned quarry in the northwest quadrant of the intersection of a medium-duty road with U. S. Route 611. The quarry is about 0.75 mile north-northwest of Pipersville, Pa.

Geologic Unit: Brunswick Formation, Triassic

Description: Grayish red, massive-bedded (3 to 4 feet thick), medium hard, slightly calcareous shale occurs immediately above the "finely laminar-like" shales collected in Sample 217-2-5. Samples 217-2-5 and 217-2-5A are very similar except the shale of this sample does not produce a laminar structure with weathering. The sample was collected from a 10 foot stratigraphic section above Sample 217-2-5.

Attitude of Bedding: N60E, 10N

Sampled Interval: Composite sample of 10 stratigraphic feet.

Type of Material: Shale

Ceramic Testing Laboratory: Norris

Chemical Analysis:

Analyst: Spectrochemical

	%
L.O.I. @ 1,000°C	4.89
H_2O Loss @ 110°C	0.22
Combined H_2O	NA
SiO_2	60.80
Al_2O_3	13.45
Fe_2O_3	7.52
FeO	0.68
CaO	2.70
MgO	2.20
CO_2	2.70
Na_2O	3.70
K_2O	3.20
TiO_2	0.76
P_2O_5	NA
MnO	NA
S (total)	0.02
C (total)	0.17

Mineralogy (X-ray):

	%	*Accuracy (±%)*
Quartz	23	6
Mica	22	6
Kaolinite	5	3
C-V-Mo	11	3
Feldspar	24	4

Remarks: Mineralogy indicates chemical analysis is low in Al_2O_3. Carbonates present.

Other Properties:

pH: 8.30
P.C.E.: NA
Water of Plasticity (%): 21.0
Drying Shrinkage (%): 1.0
Dry Strength: Good
Drying Characteristics: Good; slight checking; slight scum.
Workability: Fatty; smooth; short-working.

Slow-Firing Tests:

Temp. °F	*Color*	*Hardness*	*% Shk.*	*% Absorb.*	*% App. Por.*	*Approx. Sp. Gr.*
1800	Light brown	Fair hard	5.0	4.7	—	2.69
1900	Light brown	Fair hard	5.0	4.8	—	2.66
2000	Light brown	Hard	5.0	7.3	—	2.56
2100	Very dark brown	Very hard-glassy				
2200	Melted	—	—	—	—	—
2300	Melted	—	—	—	—	—

Pyrometric cone equivalent: NA **Bloating test:** Negative

Remarks: Poor color; too soft; scum, checking.

Bloating Tests (Quick-Firing): NA

Other Tests: Soluble Br. K. 1.25

Potential Uses: No designated ceramic use.

Remarks: See Sample 217-2-5

BUCKS COUNTY Tinicum Twp.

Sample Number
217-3-3

Quadrangle: Doylestown 15′; Lumberville 7½′

Location: Shale outcrop on the west side of Pa. Route 32 from Smithtown, Pa., north to the intersection with Dark Hollow Road.

Geologic Unit: Brunswick Formation, Triassic

Description: Grayish red (5 R 4/2) relatively unweathered wavy to irregularly bedded and thin-bedded shales are exposed along the road. The shale breaks readily into tabular-shaped fragments with irregular to relatively smooth surfaces. Small flakes of mica are observable under the microscope but no visible grain to the groundmass is evident. The shale crops out for 1,500 feet along the road.

Attitude of Bedding: N45E, 5N

Sampled Interval: Composite sample representing 1,000 feet of outcrop.

Type of Material: Shale

Ceramic Testing Laboratory: Norris

Chemical Analysis:

Analyst: McCreath	%
L.O.I. @ 1,000°C	NA
H_2O Loss @ 110°C	NA
Combined H_2O	3.32
SiO_2	50.71
Al_2O_3	18.74
Fe_2O_3	8.54
FeO	0.12
CaO	1.91
MgO	3.40
CO_2	2.22
Na_2O	4.81
K_2O	4.20
TiO_2	0.90
P_2O_5	NA
MnO	NA
S (total)	< 0.01
C (total)	0.02

Mineralogy (X-ray):

	%	*Accuracy* (±%)
Quartz	3	3
Mica	70	8
Kaolinite	0	—
C-V-Mo	0	—
Feldspar	20	5

Remarks: Mineralogy indicates chemical analysis is low in Al_2O_3. Carbonates present.

Other Properties:

pH: 8.95
P.C.E.: NA
Water of Plasticity (%): 22.0
Drying Shrinkage (%): 5.0
Dry Strength: Good
Drying Characteristics: Good; slight scum
Workability: Fatty; smooth; short-working

Slow-Firing Tests:

Temp. °F	Color	Hardness	% Shk.	% Absorb.	% App. Por.	Approx. Sp. Gr.
1800	Lt. red brown	Fair hard	5.0	5.0	—	2.67
1900	Lt. red brown	Fair hard	5.0	9.0	—	2.61
2000	Brown	Hard	8.0	11.7	—	2.46
2100	Melted	—	—	—	—	—
2200	Melted	—	—	—	—	—
2300	Melted	—	—	—	—	—

Pyrometric cone equivalent: NA **Bloating test:** Negative

Remarks: Fair color; scum; warping; too soft.

Bloating Tests (Quick-Firing): NA

Other Tests: Soluble Br. K. 1.00

Potential Uses: No designated ceramic use.

BUCKS COUNTY Plumstead Twp.

Sample Number
217-3-8

Quadrangle: Doylestown 15′; Lumberville 7½′

Location: Plumstead Township Quarry on the northeast side of Swauger Road about 0.5 mile southwest of Point Pleasant, Pa.

Geologic Unit: Lockatong Formation, Triassic.

Description: Medium-dark gray to grayish black, thick-bedded argillite with pyrite and analcime(?) is exposed in beds 6 inches to 6 feet in thickness. The rock is very hard and dense, and breaks with a conchoidal fracture. Mud cracks are present in some beds. The dimensions of the quarry are approximately 125 x 300 x 50 feet. The sample was collected from the northwestern portion of the quarry.

Attitude of Bedding: N50E, 12N

Sampled Interval: Composite of 20 stratigraphic feet of section collected from the northwest corner of the quarry.

Type of Material: Argillite

Ceramic Testing Laboratory: Tuscaloosa

Chemical Analysis:

Analyst: Conwell	%
L.O.I. @ 1,000°C	7.12
H_2O Loss @ 110°C	0.33
Combined H_2O	3.42
SiO_2	46.38
Al_2O_3	19.44
Fe_2O_3	0.93

Mineralogy (X-ray):

	%	Accuracy (±%)
Quartz	6	4
Mica	75	8
Kaolinite	0	—
C-V-Mo	0	—
Feldspar	9	2

Remarks:

Chemical Analysis:

Analyst: Conwell

	%
FeO	6.91
CaO	2.42
MgO	4.34
CO_2	3.58
Na_2O	5.50
K_2O	3.72
TiO_2	0.77
P_2O_5	NA
MnO	NA
S (total)	None
C (total)	0.07

Other Properties:

pH: 8.70
P.C.E.: NA
Water of Plasticity (%): 18.2
Drying Shrinkage (%): 2.5
Dry Strength: Low
Drying characteristics: No drying defects
Workability: Low plasticity

Slow-Firing Tests:

Temp. °F	*Color*	*Hardness*	*% Shk.*	*% Absorb.*	*% App. Por.*	*Approx. Sp. Gr.*
1800	Beige	Moh's 2	2.5	17.3	—	1.69
1900	Brown	Moh's 3	7.5	3.5	—	2.08
2000	Melted	—	—	—	—	—
2100						
2200						
2300						

Pyrometric cone equivalent: NA **Bloating test:** Positive

Remarks: Poor color; short vitrification range.

Bloating Tests (Quick-Firing):

Crushing characteristics Angular Particle size —¾″ + ½″
Drying characteristics NA Retention time 15 minutes

Temp. °F	*Bulk Density*	*Lb/Ft³*	*% Absorb.*	*Remarks*
1800				
1900	1.12	70	5.8	Excellent pore structure
2000	0.63	39	9.9	Fair pore structure; vitreous skin
2100				
2200				
2300				

Recommendations: Trial run in rotary kiln.

ROTARY KILN TESTS

Raw Material:

Screen Analysis (Crushed through a hammermill with 1½″ screen)

Size		Percent Retained
—¾″	+ ½″	43.4
—½″	+ ⅜″	17.5
—⅜″	+ 4 mesh	24.5
—4 mesh	+ 8 mesh	11.6
—8 mesh	PAN	3.0
	TOTAL	100.0

Crushing loss (—4 mesh) 14.6%

Fragment shape: Angular

Firing Data:

Size range of feed: —¾ + 4 mesh Pour weight of feed: 90.4 lb/ft³

Bloating temperature: 1980°F

Logging temperature* (*Nodules sticking together): 2060°F

Fired Material (all fired material crushed through a roll crusher)

Screen Analysis* (*ASTM Designation C 311-59T) in percentages by weight passing sieves:

Size designation	¾″	½″	⅜″	No. 4	No. 8	No. 16	No. 50	No. 100
Fine	—	—	100.0	52.5	—	14.4	6.0	4.4
Coarse	100.0	69.8	48.0	21.4	7.0	—	—	—

Loose pour weight* (ASTM* Designation C 311-59T):

Fine: 56.3 lb/ft³ Coarse: 50.6 lb/ft³

Color: Brown

COMMENTS: Best potential for lightweight aggregate product; angular lumps; very small pores; fair crushing.

Other Tests: Highly effervescent in HCl.

Potential Uses: Best potential for lightweight aggregate.

BUCKS COUNTY Plumstead Twp.

Sample Number

217-3-9

Quadrangle: Doylestown 15′; Lumberville 7½′

Location: George Wiley Quarry 0.6 mile southwest of Point Pleasant, Pa., on the southeast side of Swauger Road.

Geologic Unit: Lockatong Formation, Triassic.

Description: Medium-dark gray to dark gray, thick-bedded argillite is exposed in beds six inches to six feet in thickness. The argillite is very hard and dense and breaks with a conchoidal fracture. The dimensions of the quarry are approximately 115 x 300 x 50 feet.

Attitude of Bedding: N45E, 10N

Sampled Interval: Grab sample from the "¾ inch stone" stockpile.

Type of Material: Argillite

Ceramic Testing Laboratory: Tuscaloosa

Chemical Analysis:

Analyst: Conwell	%
L.O.I. @ 1,000°C	7.34
H_2O Loss @ 110°C	0.20
Combined H_2O	4.45
SiO_2	44.70
Al_2O_3	18.77
Fe_2O_3	2.03
FeO	6.70
CaO	2.62
MgO	3.78
CO_2	2.66
Na_2O	5.50
K_2O	3.79
TiO_2	0.86
P_2O_5	NA
MnO	NA
S (total)	None
C (total)	0.30

Mineralogy (X-ray):

	%	*Accuracy (±%)*
Quartz	14	5
Mica	68	6
Kaolinite	0	—
C-V-Mo	0	—
Feldspar	8	2

Remarks: Carbonate present.

Other Properties:

pH: 7.60
P.C.E.: NA
Water of Plasticity (%): 18.5
Drying Shrinkage (%): 0.0
Dry Strength: Low
Drying Characteristics: No drying defects
Workability: Low plasticity

Slow-Firing Tests:

Temp. °F	*Color*	*Hardness*	*% Shk.*	*% Absorb.*	*% App. Por.*	*Approx. Sp. Gr.*
1800	Beige	2	2.5	17.1	—	1.70
1900	Brown	3	10.0	4.9	—	1.99
2000	Melted	—	—	—	—	—
2100						
2200						
2300						

Pyrometric cone equivalent: NA **Bloating test:** Positive

Remarks: Poor color; short vitrification range.

Bloating Tests (Quick-Firing):

Crushing characteristics Angular Particle size: —¾″ + ½″
Drying characteristics NA Retention time 15 minutes

Temp. °F	*Bulk Density*	*Lb/Ft³*	*% Absorb.*	*Remarks*
1800				
1900	0.82	51	3.5	Good pore structure; semi-vitreous skin
2000	0.75	47	6.3	Fair pore structure; vitreous skin
2100				
2200				
2300				

Recommendations: Trial run made in rotary kiln indicates best potential for lightweight aggregate.

ROTARY KILN TESTS

Raw Material:

Screen Analysis (Crushed through a hammermill with 1½" screen)

Size		Percent Retained
—¾"	+ ½"	46.1
—½"	+ ⅜"	13.8
—⅜"	+ 4 mesh	20.8
—4 mesh	+ 8 mesh	9.9
—8 mesh	PAN	9.4
	TOTAL	100.0

Crushing loss (—4 mesh) 19.3%

Fragment shape: Angular

Firing Data:

Size range of feed: —¾ + 4 mesh Pour weight of feed: 90.4 lb/ft^3

Bloating temperature: 1880°F

Logging temperature* (*Nodules sticking together): 1930°F

Fired Material (all fired material crushed through a roll crusher)

Screen Analysis*(*ASTM Designation C 311-59T) in percentages by weight passing sieves:

Size designation	¾"	½"	⅜"	No. 4	No. 8	No. 16	No. 50	No. 100
Fine	—	—	100.0	43.1	—	11.6	5.5	4.2
Coarse	100.0	67.8	41.4	17.0	7.3	—	—	—

Loose pour weight* (*ASTM Designation C 311-59T):

Fine: 43.8 lb/ft^3 Coarse: 43.8 lb/ft^3

Color: Brown

COMMENTS: Best potential for lightweight aggregate product; angular lumps; good pore structure; good crushing.

Other Tests: Highly effervescent in HCl.

Potential Uses: Best potential for use as lightweight aggregate raw material.

Remarks: Stone presently quarried for use as concrete aggregate, road metal, and screenings.

BUCKS COUNTY Plumstead Twp.

Sample Number

217-6-1

Quadrangle: Doylestown 15'; Lumberville 7½'

Location: Quarry on the south side of Pa. Route 32, about 0.75 mile northwest of the intersection in Lumberville, Pa., of Pa. Route 32 with the road to Bulls Island (N.J.) bridge.

Geologic Unit: Lockatong Formation, Triassic.

Description: Grayish red to blackish red, massive argillite is exposed in the quarry, in beds of 6 inches to four feet in thickness. The rock is relatively fresh and difficult to break. One major joint set (with a 6 inch spacing) and a many minor joint sets make up

a prominent joint system. Microscopic examination reveals the presence of mica and quartz in a fine-grained groundmass. The height of the quarry is variable but exceeds 50 feet in places.

Attitude of Bedding: N48E, 20N

Sampled Interval: Composite sample of 25 stratigraphic feet.

Type of Material: Argillite

Ceramic Testing Laboratory: Norris

Chemical Analysis:

Analyst: Spectrochemical %

L.O.I. @ 1,000°C	2.73
H_2O Loss @ 110°C	0.09
Combined H_2O	NA
SiO_2	63.60
Al_2O_3	13.90
Fe_2O_3	6.25
FeO	0.87
CaO	2.71
MgO	1.55
CO_2	0.88
Na_2O	3.90
K_2O	3.65
TiO_2	0.75
P_2O_5	NA
MnO	NA
S (total)	< 0.01
C (total)	0.19

Mineralogy (X-ray):

	%	*Accuracy (±%)*
Quartz	21	5
Mica	33	6
Kaolinite	12	7
C-V-Mo	0	—
Feldspar	24	4

Remarks: Mineralogy indicates chemical analysis is low in Al_2O_3.

Other Properties:

pH: 8.72
P.C.E.: NA
Water of Plasticity (%): 22.0
Drying Shrinkage (%): 6.0
Dry Strength: Good
Drying Characteristics: Fair; warping; slight scum; rough
Workability: Fatty; smooth; short-working

Slow-Firing Tests:

Temp. °F	*Color*	*Hardness*	*% Shk.*	*% Absorb.*	*% App. Por.*	*Approx. Sp. Gr.*
1800	Light brown	Fair hard	6.0	4.9	—	2.66
1900	Light brown	Fair hard	6.0	5.0	—	2.62
2000	Brown	Fair hard	6.0	8.6	—	2.49
2100	Very dk brown	Very hard-glassy				
2200						
2300						

Pyrometric cone equivalent: NA **Bloating test:** Negative

Remarks: Poor color; slightly rough; scum; too soft

Bloating Tests (Quick-Firing): NA

Other Tests: Soluble Br. K. 1.10.

Potential Uses: No designated ceramic use.

Remarks: See Sample 217-6-1A. Sample 217-6-1A was sampled for comparison of test results with Sample 217-6-1.

BUCKS COUNTY Plumstead Twp.

Sample Number
217-6-1A

Quadrangle: Doylestown 15′; Lumberville 7½′

Location: Quarry on the south side of Pa. Route 32, about 0.75 mile northwest of the intersection in Lumberville, Pa., of Pa. Route 32 and the road to the Bulls Island bridge.

Geologic Unit: Lockatong Formation, Triassic.

Description: A massive, three foot thick bed of gray red argillite exposed in the lower part of the southwestern corner of the quarry was sampled for comparison of test results with Sample 217-6-1.

Attitude of Bedding: N48E, 20N

Sampled Interval: Composite of a three foot thick bed of argillite.

Type of Material: Argillite

Ceramic Testing Laboratory: Norris

Chemical Analysis:

Analyst: Spectrochemical %

L.O.I. @ 1,000°C	1.72
H_2O Loss @ 110°C	0.08
Combined H_2O	NA
SiO_2	66.10
Al_2O_3	14.20
Fe_2O_3	6.74
FeO	0.96
CaO	0.42
MgO	1.37
CO_2	ND
Na_2O	3.65
K_2O	4.00
TiO_2	0.82
P_2O_5	NA
MnO	NA
S (total)	$<$ 0.01
C (total)	0.03

Mineralogy (X-ray):

	%	Accuracy (±%)
Quartz	29	5
Mica	37	6
Kaolinite	0	—
C-V-Mo	0	—
Feldspar·	25	4

Remarks: Mineralogy indicates chemical analysis is low in Al_2O_3.

Other Properties:

pH: 8.35
P.C.E.: NA
Water of Plasticity (%): 23.0
Drying Shrinkage (%): 5.0
Dry Strength: Good
Drying Characteristics: Fair; wavy; scum
Workability: Fatty, smooth, short-working

Slow-Firing Tests:

Temp. °F	*Color*	*Hardness*	*% Shk.*	*% Absorb.*	*% App. Por.*	*Approx. Sp. Gr.*
1800	Light brown	Fair hard	5.0	6.6	—	2.58
1900	Light brown	Fair hard	5.0	7.6	—	2.56
2000	Brown	Hard	9.0	22.3	—	2.47
2100	Very dk brown	Very hard	Expanded	Shattered	—	1.53
2200	Very dk brown	Very hard	Expanded	51.1	—	1.11
2300	Very dk brown	Very hard	Expanded	48.7	—	1.10

Pyrometric cone equivalent: NA **Bloating test:** Positive (melts)

Remarks: Poor color, slight scum, wavy, sticky at 2050°F, bloats 2150°F. Good possibility for making a sintering aggregate.

Bloating Tests (Quick-Firing): NA

Other Tests: Soluble Br. K. 0.85

Potential Uses: No designated ceramic use. Slow-firing tests suggest good potential for this raw material in producing sintered aggregate.

Remarks: Sample 217-6-1A was sampled for comparison of test results with Sample 217-6-1.

BUCKS COUNTY Plumstead Twp.

Sample Number
217-6-2

Quadrangle: Doylestown 15′; Lumberville 7½′

Location: Road exposure on the south side of Pa. Route 32, about 0.8 mile northwest of the intersection in Lumberville, Pa., of Pa. Route 32 with road from Bulls Island bridge, N.J. The exposure is west of the quarry location of Samples 217-6-1 and 217-6-1A. The eastern limit of the sample interval is about 10 feet east of Bell Telephone Company pole number 95.

Geologic Unit: Lockatong Formation, Triassic.

Description: Dark gray to grayish black, thin-bedded argillite stratigraphically overlies the grey-red argillite section exposed in the quarry sampled as Sample 217-6-1. The beds range up to 6 inches in thickness, and thin toward the western portion of the outcrop. A few beds contain pinkish gray to light brown-gray laminations about 3/16 inch in thickness. The rock is difficult to break and exhibits conchoidal to irregular fractures. Microscopic examination reveals mica flakes scattered throughout the rock.

Attitude of Bedding: N45E, 20N

Sampled Interval: Composite of 10 stratigraphic feet of section.

Type of Material: Argillite

Ceramic Testing Laboratory: Norris

Chemical Analysis:

Analyst: Spectrochemical	%
L.O.I. @ 1,000°C	4.19
H_2O Loss @ 110°C	0.04
Combined H_2O	NA
SiO_2	60.10
Al_2O_3	12.40
Fe_2O_3	2.45
FeO	4.28
CaO	5.76
MgO	3.00
CO_2	2.52
Na_2O	2.12
K_2O	5.00
TiO_2	0.60

Mineralogy (X-ray):

	%	Accuracy (±%)
Quartz	24	7
Mica	46	8
Kaolinite	5	3
C-V-Mo	9	3
Feldspar	11	3

Remarks: Mineralogy indicates chemical analysis is low in Al_2O_3.

Other Properties:

pH: 8.81
P.C.E.: NA

Chemical Analysis:

Analyst: Spectrochemical %

P_2O_5	NA
MnO	NA
S (total)	$>$ 0.01
C (total)	0.22

Other Properties:

Water of Plasticity (%): 19.0
Drying Shrinkage (%): 4.0
Dry Strength: Good
Drying Characteristics: Good; wavy; scum
Workability: Fatty; smooth; short-working

Slow-Firing Tests:

Temp. °F	Color	Hardness	% Shk.	% Absorb.	% App. Por.	Approx. Sp. Gr.
1800	Pale tan	Fair hard	6.0	5.8	—	2.61
1900	Pale tan	Fair hard	6.0	6.2	—	2.56
2000	Tan	Hard	6.0	11.1	—	2.43
2100	Melted	—	—	—	—	—
2200	Melted					
2300	Melted					
2400						

Pyrometric cone equivalent: NA **Bloating test:** Positive

Remarks: Fair color; wavy; slightly rough; scum; too soft.

Bloating Tests (Quick-Firing):

Crushing characteristics: NA Particle size: NA
Drying characteristics NA Retention time: 15 minutes

Temp. °F	Bulk Density	Lb/Ft^3	% Absorb.	Remarks
1800	—	—	—	
1900	2.48	154	20.5	No expansion
2000	1.58	98	15.8	Slight expansion
2100	1.39	86	9.5	Fair expansion—overfired
2200				
2300				

Recommendations: Probably too heavy for lightweight aggregate possibilities.

Other Tests: Soluble Br. K. 1.20

Potential Uses: No designated ceramic use. Quick-firing tests indicate that lightweight aggregate made from this material would have too high a specific gravity.

Remarks: See also Samples 217-6-1 and 217-6-1A.

BUCKS COUNTY Soleburg Twp.

Sample Number

217-6-10

Quadrangle: Doylestown 15′; Lumberville 7½′

Location: Delaware Quarries operation on the south side of Pa. Route 32, about one mile east of Lumberville, Pa.

Geologic Unit: Stockton Formation, Triassic

Description: Grayish red, slightly to moderately weathered, thick bedded shales are exposed under a coarse-grained sandstone horizon of the Stockton Formation near the base of the quarry. The shale is irregularly bedded, moderately hard, and breaks with a hackly fracture. Minute flakes of mica are scattered throughout the shale. The quarry dimensions are 100 x 300 x 100 feet.

Attitude of Bedding: N50W, 12N

Sampled Interval: Composite of 15 stratigraphic feet collected near the base of the quarry.

Type of Material:

Ceramic Testing Laboratory: Tuscaloosa

Chemical Analysis:

Analyst: Conwell	%
L.O.I. @ 1,000°C	4.01
H_2O Loss @ 110°C	0.15
Combined H_2O	2.95
SiO_2	54.00
Al_2O_3	19.72
Fe_2O_3	6.48
FeO	1.08
CaO	1.61
MgO	2.36
CO_2	0.93
Na_2O	4.21
K_2O	2.93
TiO_2	0.85
P_2O_5	NA
MnO	NA
S (total)	None
C (total)	0.03

Mineralogy (X-ray):

	%	Accuracy (±%)
Quartz	33	5
Mica	31	6
Kaolinite	0	—
C-V-Mo	0	—
Feldspar	26	4

Remarks: Mineralogy indicates a higher SiO_2 content.

Other Properties:

ph: 7.50
P.C.E.: NA
Water of Plasticity (%): 25.8
Drying Shrinkage (%): 0.0
Dry Strength: Low
Drying Characteristics: No drying defects
Workability: Low plasticity

Slow-Firing Tests:

Temp. °F	*Color*	*Hardness*	*% Shk.*	*% Absorb.*	*% App. Por.*	*Approx. Sp. Gr.*
1800	Red tan	Moh's 3	0.0	20.4	—	1.64
1900	Red tan	Moh's 4	0.0	17.4	—	1.72
2000	Red brown	Moh's 5	12.5	4.5	—	2.15
2100	—	—	Expanded	—	—	—
2200						
2300						

Pyrometric cone equivalent: NA **Bloating test:** Negative

Remarks: Short vitrification range.

Bloating Tests (Quick-Firing): NA

Other Tests: Highly effervescent in HCl.

Potential Uses: No designated ceramic use.

Remarks: The quarry is presently being operated for building stone.

BUCKS COUNTY Warrington Twp.

Sample Number
217-7-1

Quadrangle: Doylestown 15′; Doylestown 7½′

Location: Eureka Stone Quarry, Inc., south of Mill Creek School and about 4.5 miles southwest of Doylestown, Pa.

Geologic Unit: Lockatong Formation, Triassic

Description: Medium-dark gray to grayish black, predominantly medium- to massive-bedded argillite is exposed in the quarry. Some of the beds are moderately calcareous and extensively fractured with some calcite fracture-filling and scattered pyrite. The dimensions of the quarry are 900 x 1300 feet in plan and 90 feet deep.

Attitude of Bedding: N45E, 8-10N

Sampled Interval: Grab sample from recently blasted material.

Type of Material: Argillite

Ceramic Testing Laboratory: Tuscaloosa

Chemical Analysis:

Analyst: Conwell	%
L.O.I. @ 1,000°C	6.15
H_2O Loss @ 110°C	0.20
Combined H_2O	3.35
SiO_2	51.32
Al_2O_3	18.58
Fe_2O_3	2.02
FeO	5.47
CaO	3.23
MgO	3.01
CO_2	3.24
Na_2O	3.85
K_2O	3.57
TiO_2	0.82
P_2O_5	NA
MnO	NA
S (total)	0.27
C (total)	0.60

Mineralogy (X-ray):

	%	Accuracy (±%)
Quartz	14	6
Mica	32	8
Kaolinite	16	7
C-V-Mo	8	3
Feldspar	20	4

Remarks: Carbonate present.

Other Properties:

pH: 7.60
P.C.E.: NA
Water of Plasticity (%): 23.7
Drying Shrinkage (%): 0.0
Dry Strength: Low
Drying Characteristics: No drying defects
Workability: Low plasticity

Slow-Firing Tests:

Temp. °F	*Color*	*Hardness*	*% Shk.*	*% Absorb.*	*% App. Por.*	*Approx. Sp. Gr.*
1800	Beige	Moh's 2	0.0	26.2	—	1.50
1900	Beige	Moh's 3	0.0	24.1	—	1.52
2000	Brown	Moh's 4	2.5	14.9	—	1.70
2100	—	—	Expanded	—	—	—
2200						
2300						

Pyrometric cone equivalent: NA **Bloating test:** Positive

Remarks: Poor color; short vitrification range.

Bloating Tests (Quick-Firing):

Crushing characteristics: Angular — Particle size: —¾″ + ½″

Drying characteristics: NA — Retention time: 15 minutes

Temp. °F	*Bulk Density*	*Lb/Ft³*	*% Absorb.*	*Remarks*
1800	—	—	—	—
1900	1.22	76	15.6	Slight bloating
2000	0.90	56	7.3	Good pore structure; vitreous skin
2100				
2200				
2300				

Remarks: Trial run in rotary kiln.

ROTARY KILN TESTS

Raw Material:

Screen Analysis (Crushed through a hammermill with 1½″ screen)

Size		*Percent Retained*
—¾″	+ ½″	44.7
—½″	+ ⅜″	13.1
—⅜″	+ 4 mesh	22.2
—4 mesh	+ 8 mesh	10.7
—8 mesh	PAN	9.3
	TOTAL	100.0

Crushing loss (—4 mesh) 20.0%

Fragment shape: Angular

Firing Data:

Size range of feed: —¾ + 4 mesh — Pour weight of feed: 92.6 lb/ft³

Bloating temperature: 2000°F

Logging temperature* (*Nodules sticking together): 2030°F

Fired Material (all fired material crushed through a roll crusher)

Screen Analysis* (*ASTM Designation C 311-59T) in percentages by weight passing sieves:

Size designation	¾″	½″	⅜″	No. 4	No. 8	No. 16	No. 50	No. 100
Fine	—	—	100.0	57.8	—	11.8	4.5	2.9
Coarse	100.0	73.4	54.5	23.0	6.2	—	—	—

Loose pour weight* (*ASTM Designation C 311-59T):

Fine: 66.9 lb/ft³ Coarse: 66.9 lb/ft³

Color: Gray

COMMENTS: Failed to meet A.S.T.M weight specifications for coarse aggregate; angular lumps; very small pores; poor crushing.

Other Tests: Highly effervescent in HCl.

Potential Uses: No designated ceramic use.

BUCKS COUNTY Warrington Twp.

Sample Number
217-8-6

Quadrangle: Doylestown 15′; Doylestown 7½′

Location: Eureka Stone Quarry, Inc., quarry on the west side of U. S. Route 611 about 0.7 mile north of Warrington, Pa.

Geologic Unit: Lockatong Formation, Triassic

Description: Medium-dark gray to grayish black, medium- to massive-bedded argillite is exposed in the quarry. Some beds are slightly to moderately calcareous with calcite-filled fractures. Disseminated pyrite is present in some beds. The quarry is 500 x 600 feet and 60 feet deep.

Attitude of Bedding: N45E, 7N

Sampled Interval: Grab sample collected from the "¾ inch stone" stockpile.

Type of Material: Argillite

Ceramic Testing Laboratory: Tuscaloosa

Chemical Analysis:

Analyst: Conwell

	%
L.O.I. @ 1,000°C	8.78
H_2O Loss @ 110°C	0.22
Combined H_2O	2.58
SiO_2	50.90
Al_2O_3	16.09
Fe_2O_3	0.96
FeO	4.32
CaO	6.25
MgO	3.86
CO_2	6.10
Na_2O	3.88
K_2O	3.72
TiO_2	0.77
P_2O_5	NA
MnO	NA
S (total)	0.10
C (total)	0.38

Mineralogy (X-ray):

	%	*Accuracy (±%)*
Quartz	11	5
Mica	58	6
Kaolinite	11	7
C-V-Mo	0	—
Feldspar	10	2

Remarks: Carbonate present.

Other Properties:

pH: 8.30
P.C.E.: NA
Water of Plasticity (%): 23.6
Drying Shrinkage (%): 0.0
Dry Strength: Low
Drying Characteristics: No drying defects
Workability: Low plasticity

Slow-Firing Tests:

Temp. °F	*Color*	*Hardness*	*% Shk.*	*% Absorb.*	*% App. Por.*	*Approx. Sp. Gr.*
1800	Beige	Moh's 1	0.0	24.8	—	1.59
1900	Beige	Moh's 1	0.0	25.1	—	1.57
2000	Brown	Moh's 4	0.0	14.6	—	1.68
2100	—	—	Expanded	—	—	—
2200						
2300						

Pyrometric cone equivalent: NA **Bloating test:** Negative

Remarks: Poor color; short vitrification range.

Bloating Tests (Quick-Firing):

Crushing characteristics: Angular Particle size: —¾" + ½"
Drying characteristics: NA Retention time: 15 minutes

Temp. °F	*Bulk Density*	*Lb/Ft³*	*% Absorb.*	*Remarks*
1800	—	—	—	
1900	1.58	98	12.1	Slight bloating
2000	0.46	29	36.5	Melting
2100				
2200				
2300				

Other Tests: Highly effervescent in HCl.

Potential Uses: No designated ceramic use.

BUCKS COUNTY Doylestown Twp.

Sample Number
217-8-7

Quadrangle: Doylestown 15′; Doylestown 7½′

Location: Edison Quarry about 0.4 mile west of Edison, Pa., near Bridge Point, Pa.

Geologic Unit: Lockatong Formation, Triassic

Description: Predominantly medium dark gray to dark gray, massive-bedded argillite is exposed in the quarry. Red argillite occurs in the south-western corner of the quarry. The exposure shows numerous slickendided surfaces and extensive development of fractures, many of which are filled with calcite. The amount of disseminated pyrite in the rock is significantly greater than that observed in other Lockatong Formation exposures in the general area of this quarry. It is suggested that the quarry may be located in a fault zone. The dimensions of the quarry are 250 x 500 x 50 feet.

Attitude of Bedding: N20W, 18S

Sampler Interval: Grab sample collected from the "¾ inch stockpile" of crushed stone.

Type of Material: Argillite

Ceramic Testing Laboratory: Tuscaloosa

Chemical Analysis:

Analyst: Conwell	%
L.O.I. @ 1,000°C	9.18
H_2O Loss @ 110°C	0.21
Combined H_2O	3.04
SiO_2	46.34
Al_2O_3	18.05
Fe_2O_3	0.00
FeO	6.34
CaO	5.14
MgO	4.85

Mineralogy (X-ray):

	%	*Accuracy (±%)*
Quartz		
Mica		
Kaolinite		
C-V-Mo		
Feldspar		

Remarks: Mineral % not determined because of low intensities; mica > feldspar > quartz > kaolinite.

Chemical Analysis:

Analyst: Conwell

	%
CO_2	5.90
Na_2O	3.89
K_2O	3.72
TiO_2	0.73
P_2O_5	NA
MnO	NA
S (total)	0.66
C (total)	0.82

Other Properties:

pH: 8.00
P.C.E.: NA
Water of Plasticity (%): 19.4
Drying Shrinkage (%): 0.0
Dry Strength: Low
Drying Characteristics: No drying defects
Workability: Low plasticity

Slow-Firing Tests:

Temp. °F	*Color*	*Hardness*	*% Shk.*	*% Absorb.*	*% App. Por.*	*Approx. Sp. Gr.*
1800	Beige	Moh's 1	0.0	29.4	—	1.49
1900	Beige	Moh's 1	0.0	29.7	—	1.50
2000	Brown	Moh's 2	0.0	25.9	—	1.54
2100	—	—	Expanded	—	—	—
2200						
2300						

Pyrometric cone equivalent: NA **Bloating test:** Positive

Remarks: Poor color; short vitrification range.

Bloating Tests (Quick-Firing):

Crushing characteristics: Angular Particle size: —¾" + ½"
Drying characteristics: NA Retention time: 15 minutes

Temp. °F	*Bulk Density*	*Lb/Ft³*	*% Absorb.*	*Remarks*
1800	—	—	—	
1900	1.33	83	9.5	Slight bloating
2000	0.73	45	17.7	Fair pore structure; semi-vitreous skin
2100	0.41	26	47.5	Some large pores; vitreous skin
2200				
2300				

Remarks: Trial run in rotary kiln.

ROTARY KILN TESTS

Raw Material:

Screen Analysis (Crushed through a hammermill with 1½" screen)

Size		*Percent Retained*
—¾"	+ ½"	49.0
—½"	+ ⅜"	11.9
—⅜"	+ 4 mesh	21.9
—4 mesh	+ 8 mesh	9.1
—8 mesh	PAN	8.1
	TOTAL	100.0

Crushing loss (—4 mesh) 17.2%

Fragment shape: Angular

Firing Data:
Size range of feed: —¾ + 4 mesh   Pour weight of feed: 97.0 lb/ft^3
Bloating temperature: 1930°F
Logging temperature* (*Nodules sticking together): 1970°F

Fired Material (all fired material crushed through a roll crusher)
Screen Analysis* (*ASTM Designation C 311-59T) in percentages by weight passing sieves:

Size designation	¾"	½"	⅜"	No. 4	No. 8	No. 16	No. 50	No. 100
Fine	—	—	100.0	38.3	—	9.3	4.5	3.6
Coarse	100.0	77.7	51.6	18.7	6.1	—	—	—

Loose pour weight* (*ASTM Designation C 311-59T):
Fine: 51.3 lb/ft^3 Coarse: 50.0 lb/ft^3
Color: Light brown

COMMENTS: Best potential for lightweight aggregate product; angular lumps; good pore structure; good crushing.

Other Tests: Highly effervescent in HCl.

Potential Uses: Best potential for lightweight aggregate.

BUCKS COUNTY Wrightstown Twp.

Sample Number
217-9-11

Quadrangle: Doylestown 15'; Buckingham 7½'

Location: Miller Quarries, Inc., on the east side of Mill Creek Road immediately south of Little Italy, Pa.

Geologic Unit: Lockatong Formation, Triassic

Description: Dark gray to blue gray, thick-bedded, well indurated argillite is exposed in beds averaging 1.5 feet in thickness. There is some interbedded red argillite exposed in the section. A few beds are slightly calcareous and some contain scattered pyrite. The argillite is only slightly weathered and breaks with a conchoidal fracture. The quarry dimensions are approximately 500 x 600 feet in plan and 50 feet deep.

Attitude of Bedding: N45W, 16N

Sampled Interval: Grab sample collected from a roadstone stockpile.

Type of Material: Argillite

Ceramic Testing Laboratory: Tuscaloosa

Chemical Analysis:

Analyst: Conwell	%
L.O.I. @ 110°C*	6.70
H_2O Loss @ 110°C	0.27
Combined H_2O	1.89
SiO_2	53.28
Al_2O_3	17.14
Fe_2O_3	3.56

Mineralogy (X-ray):

	%	*Accuracy (±%)*
Quartz	18	5
Mica	36	6
Kaolinite	12	7
C-V-Mo	0	—
Feldspar	19	4

Remarks: Calcite is present

Chemical Analysis:

Analyst: Conwell	%
FeO	3.13
CaO	4.28
MgO	2.41
CO_2	4.83
Na_2O	5.18
K_2O	3.18
TiO_2	0.85
P_2O_5	0.19
MnO	0.10
S (total)	0.00
C (total)	0.30

* Nitrogen atmosphere

Other Properties:

pH: 8.7
P.C.E.: NA
Water of Plasticity (%) 14.3
Drying Shrinkage (%) 0.0
Dry Strength: Low
Drying Characteristics: No drying defects
Workability: Low plasticity

Slow-Firing Tests:

Temp. °F	Color	Hardness	% Shk.	% Absorb.	% App. Por.	Approx. Sp. Gr.
1800	Brown	No bond	—	—	—	—
1900	Brown	Poor bond	—	—	—	—
2000	Dark brown	Poor bond	—	—	—	—
2100	—	—	Expanded	—	—	—
2200						
2300						

Pyrometric cone equivalent: NA **Bloating test:** Negative

Remarks: No ceramic bond.

Bloating Tests (Quick-Firing): NA
Crushing characteristics: Particle size:
Drying characteristics: Retention time:

Other Tests: No effervescent with HCl.
Semi-quantitative spectrographic analysis showed the following trace element abundance: Ba (>0.1%), Sr (>0.01<0.1%), Zr, and V (>0.001<0.01%). All other elements such as Zn, Cr, Cu, and Ni, if present, are less than 0.001%.

Potential Uses: No designated ceramic use.

BUCKS COUNTY Wrightstown Twp.

Sample Number
217-9-12

Quadrangle: Doylestown 15′; Buckingham 7½′

Location: Rushland Quarry, Inc., 0.2 mile northeast of Rushland, Pa., on the west side of Mill Creek Road.

Geologic Unit: Lockatong Formation, Triassic

Description: Dark gray to blue gray, thick-bedded, well indurated argillite is interbedded with a few thin-bedded shales. Cleavage is well developed in the shale. Some of the argillite is calcareous with calcite filled fractures. Pyrite is disseminated throughout the rocks. The dimensions of the quarry are 300 x 500 x 50 feet.

Attitude of Bedding: N40W, 14N

Sampled Interval: Grab sample from roadstone stockpile.
Type of Material: Argillite and shale
Ceramic Testing Laboratory: Tuscaloosa

Chemical Analysis:

Analyst: Conwell	%
L.O.I. @ 1,000°C*	11.09
H_2O Loss @ 110°C	0.17
Combined H_2O	3.04
SiO_2	44.20
Al_2O_3	15.99
Fe_2O_3	2.00
FeO	4.91
CaO	8.12
MgO	3.77
CO_2	8.31
Na_2O	4.86
K_2O	3.68
TiO_2	0.65
P_2O_5	0.18
MnO	0.14
S (total)	0.49
C (total)	0.52

* Nitrogen atmosphere

Mineralogy (X-ray):

	%	Accuracy (±%)
Quartz	12	5
Mica	59	6
Kaolinite	0	—
C-V-Mo	0	—
Feldspar	14	3

Remarks: Carbonates present

Other Properties:
pH: 8.00
P.C.E.: NA
Water of Plasticity (%): 21.3
Drying Shrinkage (%): 0.0
Dry Strength: Low
Drying Characteristics: No drying defects
Workability: Low plasticity

Slow-Firing Tests:

Temp. °F	*Color*	*Hardness*	*% Shk.*	*% Absorb.*	*% App. Por.*	*Approx. Sp. Gr.*
1800	Beige	Moh's 1	0.0	27.5	—	1.50
1900	Beige	Moh's 1	0.0	27.4	—	1.48
2000	Brown	Moh's 4	0.0	17.6	—	1.54
2100	—	—	Expanded	—	—	—
2200	—	—	—	—	—	—
2300	—	—	—	—	—	—

Pyrometric cone equivalent: NA **Bloating test:** Positive
Remarks: Poor color; short vitrification range.
Bloating Tests (Quick-Firing):
Crushing characteristics: Angular Particle size: —¾" + ½"
Drying characteristics: NA Retention time: 15 minutes

Temp. °F	*Bulk Density*	*Lb/Ft³*	*% Absorb.*	*Remarks*
1800				
1900	0.94	58	8.3	Fair pore structure; semi-vitreous skin
2000	0.83	52	24.5	Fair pore structure; vitreous skin
2100	—	—	—	Selective melting
2200				
2300				

Remarks: Trial run in rotary kiln.

ROTARY KILN TESTS

Raw Material:

Screen Analysis (Crushed through a hammermill with 1½" screen)

Size		Percent Retained
—¾"	+ ½"	43.1
—½"	+ ⅜"	14.4
—⅜"	+ 4 mesh	22.5
—4 mesh	+ 8 mesh	10.5
—8 mesh	PAN	9.5
	TOTAL	100.0

Crushing loss (—4 mesh) 20.0%

Fragment shape: Angular

Firing Data:

Size range of feed: —¾ + 4 mesh   Pour weight of feed: 90.8 lb/ft³
Bloating temperature: 1940°F
Logging temperature* (*Nodules sticking together): 1980°F

Fired Material (all fired material crushed through a roll crusher)
Screen Analysis* (*ASTM Designation C 311-59T) in percentages by weight passing sieves:

Size designation	¾"	½"	⅜"	No. 4	No. 8	No. 16	No. 50	No. 100
Fine	—	—	100.0	37.3	—	7.9	3.3	2.4
Coarse	100.0	71.9	46.5	20.8	9.1	—	—	—

Loose pour weight* (*ASTM Designation C 311-59T):
Fine: 47.5 lb/ft³   Coarse: 48.1 lb/ft³
Color: Gray

COMMENTS: Best potential for lightweight aggregate product; angular lumps; good pore structure; fair crushing.

Other Tests: Highly effervescent in HCl.
Semi-quantitative spectrographic analysis shows the following trace elements abundance: Ba (>0.1%), Sr (>0.01%), Zr, V, and Pb (>0.001<0.01%). Other elements such as Zn, Cr, Cu, and Ni, if present, are less than 0.001%.

Potential Uses: Best potential for use as a lightweight aggregate raw material.

BUCKS COUNTY Upper Makefield Twp.

Sample Number
227-8-1

Quadrangle: Lambertville 15'; Pennington 7½'

Location: Abandoned quarry 1.7 miles south-southwest of Washington Crossing, Pa., on the west side of the macadam road running west of, and parallel to, the Pennsylvania Canal.

Geologic Unit: Lockatong Formation, Triassic

Description: Interbedded red and dark gray to black, thick-bedded argillite is exposed in beds averaging 1.5 feet in thickness. Locally some beds consist of regularly spaced, narrow, light to dark bands which are often visible on weathered joint surfaces. The

rock is slightly to moderately weathered. Thin coatings of calcite crystals occur on some joint surfaces, and disseminated pyrite and analcime is present in some beds. The argillite is well indurated and breaks with a conchoidal fracture. The quarry dimensions are 100 x 200 x 50 feet.

Attitude of Bedding: N85W, 9N

Sampled Interval: Composite sample of 20 stratigraphic feet collected at the north end of the quarry.

Type of Material: Argillite

Ceramic Testing Laboratory: Tuscaloosa

Chemical Analysis:

Analyst: Conwell	%
L.O.I. @ 1,000°C*	6.65
H_2O Loss @ 110°C	0.76
Combined H_2O	6.52
SiO_2	58.64
Al_2O_3	24.77
Fe_2O_3	2.10
FeO	0.71
CaO	0.00
MgO	0.79
CO_2	0.00
Na_2O	0.23
K_2O	3.68
TiO_2	1.29
P_2O_5	0.06
MnO	0.07
S (total)	0.00
C (total)	0.15

* Nitrogen atmosphere

Mineralogy (X-ray):

	%	Accuracy (±%)
Quartz	11	5
Mica	51	6
Kaolinite	9	6
C-V-Mo	0	—
Feldspar	14	4

Remarks: Analcime is present

Other Properties:

pH: 8.8
P.C.E.: NA
Water of Plasticity (%): 12.7
Drying Shrinkage (%): 0.0
Dry Strength: Low
Drying Characteristics: No drying defects
Workability: Low plasticity

Slow-Firing Tests:

Temp. °F	*Color*	*Hardness*	*% Shk.*	*% Absorb.*	*% App. Por.*	*Approx. Sp. Gr.*
1800	Brown	Poor bond	—	—	—	—
1900	Brown	Poor bond	—	—	—	—
2000	Dark brown	Poor bond	—	—	—	—
2100	—	—	Expanded	—	—	—
2200						
2300						

Pyrometric cone equivalent: NA **Bloating test:** Positive

Remarks: Not suitable for use in vitreous clay products. No ceramic bond; may be limy.

Bloating Tests (Quick-Firing):
Crushing characteristics: Angular — Particle size: ¾" lumps
Drying characteristics: NA — Retention time: 15 minutes

Temp. °F	Bulk Density gm/cc	Lb/Ft³	% Absorb.	Remarks
1800	—	—	—	
1900	1.91	119.2	9.0	No expansion
2000	0.69	43.1	8.5	Good pore structure
2100	1.05	65.5	13.7	Overfired; vitreous
2200				
2300				

Recommendations: Marginal for lightweight aggregate (short firing range).

Other Tests: Highly effervescent with HCl.
Semi-quantitative spectrographic analysis shows the following trace element abundance: Ba (>0.1%), Sr, and V (0.01 to 0.1%). Other elements such as Zn, Cu, Cr, and Ni, if present, are less than 0.001%.

Potential Uses: Quick-firing tests indicate this may be a marginal material for lightweight aggregate.

CHESTER COUNTY Honeybrook Twp.

Sample Number
188-8-4

Quadrangle: Honeybrook 15′; Wagontown 7½′

Location: Open trench on the south side of U. S. Route 322, about 0.3 mile east of Rockville, Pa.

Geologic Unit: Anorthosite, Residual Soil, Precambrian

Description: The sample was collected from a trench 4.5 feet deep, which was dug for laying pipe to the Brandywine Mobile Home Park, Inc. The soil in the trench is generally stony and large boulders are present to within one foot of the surface in some places. The color of the soil is light to moderate brown (5 YR 5/6 to 5 YR 4/4).

Attitude of Bedding: Not measurable

Sampled Interval: Vertical channel sample of the trench.

Type of Material: Residual soil

Ceramic Testing Laboratory: Tuscaloosa

Chemical Analysis:

Analyst: Conwell	%
L.O.I. @ 1,000°C	10.58
H_2O Loss @ 110°C	2.30
Combined H_2O	10.10
SiO_2	42.54
Al_2O_3	22.87
Fe_2O_3	15.14

Mineralogy (X-ray):

	%	Accuracy (±%)
Quartz		
Mica		
Kaolinite		
C-V-Mo		
Feldspar		

Remarks: Mineral percentage not determined

Chemical Analysis:

Analyst: Conwell

	%
FeO	0.50
CaO	0.50
MgO	1.93
CO_2	0.35
Na_2O	0.52
K_2O	0.55
TiO_2	2.46
P_2O_5	NA
MnO	NA
S (total)	None
C (total)	0.87

Mineralogy (X-ray):

% Accuracy (±%)

because of low intensities; Kaolinite > mica > quartz > C-V-Mo > feldspar.

Other Properties:

pH: 6.60
P.C.E.: NA
Water of Plasticity (%): 35.6
Drying Shrinkage (%): 2.5 Dry Strength; Low
Drying Characteristics: No defects
Workability: Low plasticity

Slow-Firing Tests:

Temp. °F	Color	Hardness	% Shk.	% Absorb.	% App. Por.	Approx. Sp. Gr.
1800	Brown	Moh's 2	5.0	33.6	48.7	1.45
1900	Brown	Moh's 2	5.0	32.3	47.8	1.48
2000	Brown	Moh's 2	5.0	28.4	44.9	1.58
2100	Brown	Moh's 3	7.5	25.9	42.5	1.64
2200	—	—	Expanded	—	—	—
2300						

Pyrometric cone equivalent: NA **Bloating test:** Negative

Remarks: High absorption at all temperatures. Not suitable for use as a principal component in vitreous clay products.

Bloating Tests (Quick-Firing): NA

Other Tests: Not effervescent with HCl.

Potential Uses: No designated ceramic use.

CHESTER COUNTY Schuylkill Twp.

Sample Number
198-6-1A

Quadrangle: Phoenixville 15′; Phoenixville 7½′

Location: Railroad cut at north end of Penn Central Railroad Co. tunnel, about 0.2 mile south of Cromby, Pa.

Geologic Unit: Lockatong Formation, Triassic

Description: Grayish red, slightly calcareous, fissile to thin-bedded shales occur at the base of the exposed section in the Penn Central Railroad cut at the north end of the tunnel. The beds range from ¼ inch to 5 inches in thickness.

Attitude of Bedding: N70-80W, 12N

Sampled Interval: The sample represents 6 stratigraphic feet.

Type of Material: Shale

Ceramic Testing Laboratory: Norris

Chemical Analysis:

Analyst: McCreath	%
L.O.I. @ 1,000°C	NA
H_2O Loss @ 110°C	NA
Combined H_2O	3.71
SiO_2	54.70
Al_2O_3	18.38
Fe_2O_3	7.03
FeO	0.17
CaO	2.37
MgO	2.33
CO_2	2.01
Na_2O	3.53
K_2O	4.91
TiO_2	0.83
P_2O_5	NA
MnO	NA
S (total)	< 0.02
C (total)	0.08

Mineralogy (X-ray):

	%	Accuracy (±%)
Quartz	16	5
Mica	34	7
Kaolinite	3	2
C-V-Mo	6	3
Feldspar	31	4

Remarks:

Other Properties:

pH: 9.30
P.C.E.: NA
Water of Plasticity (%): 22.0
Drying Shrinkage (%): 4.0
Dry Strength: Good
Drying Characteristics: Fair; checks, warping
Workability: Short working, smooth, fatty

Slow-Firing Tests:

Temp. °F	*Color*	*Hardness*	*% Shk.*	*% Absorb.*	*% App. Por.*	*Approx. Sp. Gr.*
1800	Light brown	Fair hard	4.0	5.1	—	2.61
1900	Light brown	Hard	6.0	5.9	—	2.65
2000	Brown	Very hard	10.0	13.2	—	2.46
2100	Dark brown	Steel hard	14.5	0.5	—	2.30
2200	Melted	—	—	—	—	—
2300						

Pyrometric cone equivalent: NA **Bloating test:** Positive

Remarks: Fair color; slight scum, warping, color needs improving. Addition of barium salts would improve.

Bloating Tests (Quick-Firing):

Crushing characteristics: Shaly Particle size: —¾" + ½"
Drying characteristics: Good Retention time: 15 minutes

Temp. °F	*Bulk Density*	*Lb/Ft³*	*% Absorb.*	*Remarks*
1800	—	—	—	
1900	2.30	144	1.2	Very slight expansion
2000	1.74	119	1.3	Slight expansion
2100	1.50	94	2.2	Fair expansion
2200				Melted
2300				

Recommendations: A little heavy for lightweight aggregate possibility.

Other Tests: Soluble Br. K. 1.00

Potential Uses: Face brick, if color improved

Remarks: Also see Sample 198-6-1B

CHESTER COUNTY Schuylkill Twp.

Sample Number
198-6-1B

Quadrangle: Phoenixville 15′; Phoenixville 7½′

Location: Railroad cut at the north end of the Penn Central Railroad Company tunnel, about 0.2 mile south of Cromby, Pa.

Geologic Unit: Lockatong Formation, Triassic

Description: Grayish red, very slightly calcareous, massive-bedded mudstones interbedded with some fissile shales occur over a stratigraphic interval of 10 feet above Sample 198-6-1A. The massive shale attains a thickness of three feet.

Attitude of Bedding: N70-80W, 12N

Sampled Interval: Composite of 10 stratigraphic feet.

Type of Material: Mudstone and shale

Ceramic Testing Laboratory: Norris

Chemical Analysis:

Analyst: McCreath	%
L.O.I. @ 1,000°C	NA
H_2O Loss @ 110°C	NA
Combined H_2O	2.42
SiO_2	53.88
Al_2O_3	17.64
Fe_2O_3	7.51
FeO	0.14
CaO	2.91
MgO	2.31
CO_2	3.88
Na_2O	5.23
K_2O	3.38
TiO_2	0.87
P_2O_5	NA
MnO	NA
S (total)	< 0.01
C (total)	0.09

Mineralogy (X-ray):

	%	Accuracy (±%)
Quartz	15	5
Mica	48	6
Kaolinite	11	7
C-V-Mo	0	
Feldspar	16	3

Remarks: Carbonate present.

Other Properties:

pH: 9.90
P.C.E.: NA
Water of Plasticity (%): 22.0
Drying Shrinkage (%): 4.0
Dry Strength: Good
Drying Characteristics: Good, slight checking
Workability: Short-working, smooth, fatty

Slow-Firing Tests:

Temp. °F	Color	Hardness	% Shk.	% Absorb.	% App. Por.	Approx. Sp. Gr.
1800	Light brown	Fair hard	4.5	5.1	—	2.65
1900	Light brown	Hard	4.5	5.2	—	2.62
2000	Brown	Very hard	5.5	6.8	—	2.50
2100	Dark brown	Steel hard	11.0	1.7	—	2.20
2200	Melted	—	—	—	—	—
2300						

Pyrometric cone equivalent: NA **Bloating test:** Positive

Remarks: Fair color, slight warping

Bloating Tests (Quick-Firing):

Crushing characteristics: Good — Particle size: —¾″ + ½″
Drying characteristics: Good — Retention time: 15 minutes

Temp. °F	*Bulk Density*	*Lb/Ft³*	*% Absorb.*	*Remarks*
1800	—	—	—	
1900	2.50	156	2.5	No expansion
2000	2.31	144	1.4	Very slight expansion
2100	1.42	89	4.3	Fair expansion
2200				Melted
2300				

Recommendations: A little heavy for lightweight aggregate possibility.

Other Tests: Soluble Br. K. 1.11

Potential Uses: Face brick

Remarks: Also see Sample 198-6-1A

CHESTER COUNTY New Garden Twp.

Sample Number
199-7-1

Quadrangle: West Chester 15′; Kennett Square 7½′

Location: A clay pit about 0.4 mile south-southwest of Kaolin, Pa., on the east side of an unpaved road leading south out of Kaolin to a small stream called Broad Run.

Geologic Unit: Residual clay from pegmatite dike, Precambrian

Description: A sample was collected from a stockpile of yellow-buff clay located adjacent to an old clay pit in the weathered zone of a pegmatite dike. The depth of workings in the pit indicate the clay is probably only three to five feet thick. The clay is a decomposition product of the feldspar in the pegmatite and is considered to be best developed in close proximity to the regional drainage system.

Attitude of Bedding: Pegmatite dike strikes N45E.

Sampled Interval: Grab sample from stockpile.

Type of Material: Residual clay

Ceramic Testing Laboratory: Norris

Chemical Analysis:

Analyst: Spectrochemical	%
L.O.I. @ 1,000°C	9.13
H_2O Loss @ 110°C	0.14
Combined H_2O	NA
SiO_2	50.90
Al_2O_3	33.40
Fe_2O_3	2.90
FeO	ND
CaO	0.08
MgO	0.40

Mineralogy (X-ray):

	%	*Accuracy (±%)*
Quartz	19	5
Mica	24	8
Kaolinite	50	10
C-V-Mo	0	—
Feldspar	1	1
Remarks:		

Chemical Analysis:

Analyst: Spectrochemical %

CO_2	ND
Na_2O	0.17
K_2O	2.70
TiO_2	0.22
P_2O_5	NA
MnO	NA
S (total)	$>$ 0.01
C (total)	0.14

Other Properties:

pH: 7.00
P.C.E.: 21-22
Water of Plasticity (%): 38.0
Drying Shrinkage (%): 0.0
Dry Strength: Fair
Drying Characteristics: Good; mica on surface
Workability: Fatty; smooth; short-working

Slow-Firing Tests:

Temp. °F	Color	Hardness	% Shk.	% Absorb.	% App. Por.	Approx. Sp. Gr.
1800	Flesh	Soft	1.0	3.3	—	2.22
1900	Flesh	Soft	4.0	3.3	—	2.27
2000	Pink	Soft	4.0	3.4	—	2.26
2100	Pink	Soft	4.0	3.4	—	2.28
2200	Pink	Fair hard	5.0	3.9	—	2.24
2300	Off white	Fair hard	6.0	5.6	—	2.27
2400						

Pyrometric cone equivalent: 21-22 **Bloating test:** Negative
Cone color: Spotty gray

Remarks: Light color, too soft below 2400°F, laminated separations (due to mica?).

Bloating Tests (Quick-Firing): NA

Other Tests: Soluble Br. K. 0.50

Potential Uses: Possible flue brick and low-duty refractory with possible high shrinkage.

Remarks: Estimates of clay reserves would require a detailed program of test augering in the surrounding area.

CUMBERLAND COUNTY Hopewell Twp.

Sample Number
118-6-2

Quadrangle: Shippensburg 15′

Location: Outcrop reached by traveling west along Pa. Route 641, 0.7 mile from Newburg, Pa. to undesignated crossroad, turn south and travel 300 feet to shale exposure on the east side of the road.

Geologic Unit: Martinsburg Formation, Ordovician

Description: The outcrop consists of intensely faulted, moderately weathered shales, siltstones, and a few thin sandstones. The fresh shale is olive gray (5Y 4/1) and weathers to moderate yellowish brown (10 YR 5/4). Concentrations of secondary quartz are present in the southern part of the outcrop.

Attitude of Bedding: N50E, variable dip to the north

Sampled Interval: Composite sample taken 2 feet across the outcrop.

Type of Material: Shale

Ceramic Testing Laboratory: Tuscaloosa

Chemical Analysis:

Analyst: Conwell

	%
L.O.I. @ 1,000°C	5.45
H_2O Loss @ 110°C	0.73
Combined H_2O	5.12
SiO_2	61.72
Al_2O_3	17.66
Fe_2O_3	4.34
FeO	2.30
CaO	1.11
MgO	2.77
CO_2	0.00
Na_2O	0.78
K_2O	2.84
TiO_2	0.91
P_2O_5	NA
MnO	NA
S (total)	0.03
C (total)	0.52

Mineralogy (X-ray):

	%	Accuracy (±%)
Quartz	30	5
Mica	49	7
Kaolinite	6	4
C-V-Mo	8	3
Feldspar	2	1

Remarks:

Other Properties:

pH: 5.90
P.C.E.: NA
Water of Plasticity (%): 20.3
Drying Shrinkage (%): 2.5
Dry Strength: Low
Drying Characteristics: No defects
Workability: Low plasticity

Slow-Firing Tests:

Temp. °F	*Color*	*Hardness*	*% Shk.*	*% Absorb.*	*% App. Por.*	*Approx. Sp. Gr.*
1800	Tan	Moh's 2	2.5	17.4	—	1.81
1900	Light brown	Moh's 3	2.5	13.0	—	1.94
2000	Brown	Moh's 4	5.0	8.5	—	2.09
2100	Dark brown	Moh's 5	7.5	1.7	—	2.17
2200	—	—	Expanded	—	—	—
2300						

Pyrometric cone equivalent: NA **Bloating test:** Positive

Bloating Tests (Quick-Firing):

Crushing characteristics: Angular Particle size: ¾" lumps
Drying characteristics: NA Retention time: 15 minutes

Temp. °F	*Bulk Density*	*Lb/Ft³*	*% Absorb.*	*Remarks*
1800	—	—	—	
1900	1.28	79.7	6.8	Slight expansion
2000	1.12	69.9	6.3	Fair expansion
2100	0.71	44.3	10.3	Overfired—vitreous
2200				
2300				

Recommendations: Promising lightweight aggregate; trial run in rotary kiln should be made.

ROTARY KILN TESTS:

Raw Material:

Screen Analysis (Crushed through a hammermill with 1½" screen)

Size		*Percent Retained*
—¾"	+ ½"	13.8
—½"	+ ⅜"	12.5
—⅜"	+ 4 mesh	33.9
—4 mesh	+ 8 mesh	13.6
—8 mesh	PAN	26.2
	TOTAL	100.0

Crushing loss (—4 mesh) 39.8%

Fragment shape: Angular and platy

Firing Data

Size range of feed: —¾ + 4 mesh Pour weight of feed: 84.0 lb/ft³
Bloating temperature: 2000°F
Logging temperature* (*Nodules sticking together): 2090°F

Fired Material (all fired material crushed through a roll crusher)
Screen Analysis* (*ASTM Designation C 311-59T) in percentages by weight passing sieves:

Size designa-tion	¾"	½"	⅜"	No. 4	No. 8	No. 16	No. 50	No. 100
Fine	—	—	100.0	57.8	—	21.8	4.4	3.0
Coarse	100.0	82.0	58.0	10.0	5.2	—	—	—

Loose pour weight* (*ASTM Designation C 311-59T):
Fine: 55.0 lb/ft³ Coarse: 50.0 lb/ft³
Color: Tan to dark brown

COMMENTS: Angular and tabular fragments; fair pore structure; fair crushing; undersirable mixture of bloating and non-bloating materials; marginal for lightweight aggregate.

Other Tests: Not effervescent with HCl.

Potential Uses: Face brick; fair quality lightweight aggregate might possibly be made from this material.

CUMBERLAND COUNTY Upper Mifflin Twp.

Sample Number
128-1-4

Quadrangle: Newville 15′; Newville 7½′

Location: Quarry on the north side of Pa. Route 997 (U.S.G.S. Topographic quadrangle maps incorrectly list the number as 944) 0.6 mile northeast of Washington, Pa.

Geologic Unit: Martinsburg Formation, Ordovician

Description: A series of shales and siltstones are capped by a sandstone 2 feet thick in a quarry 100 feet long and 12 feet high. The fresh rock is olive gray (5 Y 4/1), but weathers to greenish gray (5 G 6/1).

Attitude of Bedding: N45E, 75S; variable due to faulting.

Sampled interval: Composite sample of the quarry

Type of Material: Shale

Ceramic Testing Laboratory: Tuscaloosa

Chemical Analysis:

Analyst: Conwell

	%
L.O.I. @ 1,000°C	5.34
H_2O Loss @ 110°C	0.93
Combined H_2O	4.57
SiO_2	61.54
Al_2O_3	17.31
Fe_2O_3	5.74
FeO	1.51
CaO	0.30
MgO	2.64
CO_2	0.10
Na_2O	0.73
K_2O	2.88
TiO_2	0.83
P_2O_5	NA
MnO	NA
S (total)	None
C (total)	0.46

Mineralogy (X-ray):

	%	Accuracy (±%)
Quartz	29	5
Mica	53	6
Kaolinite	4	3
C-V-Mo	7	3
Feldspar	2	1

Remarks:

Other Properties:

pH: 6.80
P.C.E.: NA
Water of Plasticity (%): 17.8
Drying Shrinkage (%): 2.5
Dry Strength: Low
Drying Characteristics: No defects
Workability: Low plasticity

Slow-Firing Tests:

Temp. °F	Color	Hardness	% Shk.	% Absorb.	% App. Por.	Approx. Sp. Gr.
1800	Tan	Moh's 2	5.0	14.2	—	1.89
1900	Light brown	Moh's 3	5.0	11.7	—	1.97
2000	Brown	Moh's 4	7.5	6.6	—	2.16
2100	Dark brown	Moh's 5	10.0	0.7	—	2.19
2200	—	—	Expanded	—	—	—
2300						

Pyrometric cone equivalent: NA **Bloating test:** Positive

Remarks:

Bloating Tests (Quick-Firing):
Crushing characteristics: Platy Particle size: ¾" lumps
Drying characteristics: NA Retention time: 15 minutes

Temp. °F	Bulk Density	Lb/Ft^3	% Absorb.	Remarks
1800	—	—	—	
1900	1.91	119.2	5.3	No expansion
2000	1.42	88.6	4.4	Fair expansion
2100	1.06	66.1	4.4	Good expansion
2200				
2300				

Recommendations: Promising raw material for lightweight aggregate; trial run in rotary kiln should be made.

ROTARY KILN TESTS:

Raw Material:

Screen Analysis (Crushed through a hammermill with 1½" screen)

Size		Percent Retained
—¾"	+ ½"	28.4
—½"	+ ⅜"	15.1
—⅜"	+ 4 mesh	25.5
—4 mesh	+ 8 mesh	9.3
—8 mesh	PAN	21.7
	TOTAL	100.0

Crushing loss (—4 mesh) 31.0%

Fragment shape: Angular

Firing Data:

Size range of feed: —¾ + 4 mesh Pour weight of feed: 77.0 lb/ft³
Bloating temperature: 2020°F
Logging temperature* (*Nodules sticking together): 2050°F

Fired Material (all fired material crushed through a roll crusher)
Screen Analysis* (*ASTM Designation C 311-59T) in percentages by weight passing sieves:

Size designation	¾"	½"	⅜"	No. 4	No. 8	No. 16	No. 50	No. 100
Fine	—	—	100.0	64.0	—	24.0	11.3	8.4
Coarse	100.0	69.0	41.0	9.0	5.5	—	—	—

Loose pour weight* (*ASTM Designation C 311-59T):
Fine: 52.5 lb/ft³ Coarse: 50.0 lb/ft³
Color: Tan to brown

COMMENTS: Not promising for lightweight aggregate. Tabular and angular fragments; good pore structure; good crushing. Some non-bloating materials; short firing range.

Other Tests: Not effervescent with HCl.

Potential Uses: "MW" face brick specifications at about 1950°F. Brick has low green strength and poor color.

Remarks: Quarry is operated for fill material.

CUMBERLAND COUNTY Lower Frankford Twp.

Sample Number
128-3-3

Quadrangle: Newville 15'; Plainfield 7½'

Location: Quarry in the northern corner of the Plainfield 7½' Topographic map approximately 1.6 miles southeast of "Stone Church and School". The quarry is on the east side of an undesignated road.

Geologic Unit: Martinsburg Formation, Ordovician

Description: The shale is slightly to moderately weathered, and breaks into ¼ inch thick fragments. The fresh shale is medium-olive gray (5 Y 5/1) and weathered to moderate yellowish-brown (19 YR 5/4). The quarry face is 210 feet long and 10 feet high.

Attitude of Bedding: N65W, 75N; Cleavage: N65°W, 65S

Sampled Interval: Channel sample of the quarry wall.

Type of Material: Shale

Ceramic Testing Laboratory: Tuscaloosa

Chemical Analysis:

Analyst: Conwell

	%
L.O.I. @ 1,000°C	5.47
H_2O Loss @ 110°C	0.58
Combined H_2O	4.17
SiO_2	61.32
Al_2O_3	18.51
Fe_2O_3	5.23
FeO	1.87
CaO	0.20
MgO	2.61
CO_2	0.20
Na_2O	0.68
K_2O	3.16
TiO_2	0.82
P_2O_5	NA
MnO	NA
S (total)	0.02
C (total)	0.49

Mineralogy (X-ray):

	%	Accuracy (±%)
Quartz	31	5
Mica	48	6
Kaolinite	6	3
C-V-Mo	9	3
Feldspar	1	1

Remarks:

Other Properties:

pH: 5.80
P.C.E.: NA
Water of Plasticity (%): 18.6
Drying Shrinkage (%): 0.0
Dry Strength: Low
Drying Characteristics: No defects
Workability: Low plasticity

Slow-Firing Tests:

Temp. °F	*Color*	*Hardness*	*% Shk.*	*% Absorb.*	*% App. Por.*	*Approx. Sp. Gr.*
1800	Tan	Moh's 3	2.5	13.8	26.5	1.92
1900	Light brown	Moh's 4	2.5	10.5	21.1	2.01
2000	Brown	Moh's 5	7.5	8.1	17.0	2.10
2100	Red-brown	Moh's 6	7.5	1.5	3.3	2.22
2200	—	—	Expanded	—	—	—
2300						

Pyrometric cone equivalent: NA **Bloating test:** Positive

Remarks: Should fire to "SW" face brick specifications at 2000°F. Poor color.

Bloating Tests (Quick-Firing):

Crushing characteristics: Angular Particle size: ¾" lumps
Drying characteristics: NA Retention time: 15 minutes

Temp. °F	*Bulk Density*	*Lb/Ft³*	*% Absorb.*	*Remarks*
1800	—	—	—	
1900	1.92	119.8	9.5	No expansion
2000	1.76	109.8	9.8	No expansion
2100	0.81	50.5	9.7	Good pore structure; vitreous
2200				
2300				

Recommendations: Marginal for lightweight aggregate.

ROTARY KILN TESTS:

Raw Material:

Screen Analysis (Crushed through a hammermill with 1½" screen)

Size		Percent Retained
—¾"	+ ½"	19.9
—½"	+ ⅜"	16.4
—⅜"	+ 4 mesh	34.3
—4 mesh	+ 8 mesh	8.4
—8 mesh	PAN	21.0
	TOTAL	100.0

Crushing loss (—4 mesh) 29.4%

Fragment shape: Platy

Firing Data:

Size range of feed: —¾ + 4 mesh   Pour weight of feed: 83.0 lb/ft³

Bloating temperature: 1980°F

Logging temperature* (*Nodules sticking together): 2000°F

Fired Material (all fired material crushed through a roll crusher)

Screen Analysis* (*ASTM Designation C 311-59T) in percentages by weight passing sieves:

Size designation	¾"	½"	⅜"	No. 4	No. 8	No. 16	No. 50	No. 100
Fine	—	—	100.0	62.0	—	18.0	6.6	4.6
Coarse	100.0	88.0	61.0	9.0	3.5	—	—	—

Loose pour weight* (*ASTM Designation C 311-59T):

Fine: 45.0 lb/ft³   Coarse: 37.5 lb/ft³

Color: Dark brown

COMMENTS: Marginal for lightweight aggregate. Angular and tabular fragments; some large pores. Short range.

Other Tests: Not effervescent with HCl.

Potential Uses: Should fire to "SW" face brick at 2000°F, but the color is poor. Rotary kiln tests indicate good specific gravity lightweight aggregate can be made with material but other factors, such as firing range, are not very satisfactory. Fair to good quality lightweight aggregate might be made from the material, depending upon processing techniques for improving such factors as firing range.

Remarks: The quarry is operated for fill material.

CUMBERLAND COUNTY   Middlesex Twp.

Sample Number
137-8-3A

Quadrangle: New Bloomfield 15′; Wertzville 7½′

Location: Quarry on the north side of Pa. Route 944 about 1.2 miles west of Donnellytown, Pa.

Geologic Unit: Martinsburg Formation, Ordovician

Description: Medium to medium-dark gray, fissile to very thin-bedded shale interbedded with a few silty shale beds, several inches thick, is exposed in the quarry. The sample was collected in the eastern portion of the quarry where the shale is only slightly weathered. The shale fragments are mostly tabular with irregular to hackly edges. The northern and western quarry faces are more intensely weathered. The quarry is approximately 80 feet wide, 200 feet long and 15 feet high.

Attitude of Bedding: N75E, 55S

Sampled Interval: Composite sample of 25 stratigraphic feet.

Type of Material: Shale

Ceramic Testing Laboratory: Norris

Chemical Analysis:

Analyst: Spectrochemical

	%
L.O.I. @ 1,000°C	5.84
H_2O Loss @ 110°C	0.56
Combined H_2O	NA
SiO_2	64.80
Al_2O_3	12.30
Fe_2O_3	2.63
FeO	4.77
CaO	1.60
MgO	1.85
CO_2	2.02
Na_2O	1.58
K_2O	3.68
TiO_2	0.88
P_2O_5	NA
MnO	NA
S (total)	0.14
C (total)	0.24

Mineralogy (X-ray):

	%	Accuracy (±%)
Quartz	44	5
Mica	40	6
Kaolinite	0	—
C-V-Mo	0	—
Feldspar	11	3

Remarks: Mineralogy indicates chemical analysis is low in Al_2O_3.

Other Properties:

pH: 9.10
P.C.E.: NA
Water of Plasticity (%): 13.8
Drying Shrinkage (%): 0.
Dry Strength: Fair
Drying Characteristics: Fair; checking; rough surface; scum
Workability: Mealy; smooth; short-working

Slow-Firing Tests:

Temp. °F	*Color*	*Hardness*	*% Shk.*	*% Absorb.*	*% App. Por.*	*Approx. Sp. Gr.*
1800	Pale tan	Fair hard	0.0	7.5	—	2.63
1900	Tan	Fair hard	0.0	8.0	—	2.58
2000	Brown	Hard	1.0	10.3	—	2.50
2100	Dark brown	Very hard	0.0	21.0	—	1.83
2200	Black	Hard	Expanded	21.5	—	0.81
2300						

Pyrometric cone equivalent: NA **Bloating test:** Positive

Remarks: Poor color; checking; rough surface; expansion; high absorption.

Bloating Tests (Quick-Firing):

Crushing characteristics: Good Particle size: —¾" + ½"
Drying characteristics: Good Retention time: 15 minutes

Temp. °F	*Bulk Density*	*Lb/Ft³*	*% Absorb.*	*Remarks*
1800	—	—	—	
1900	—	—	—	
2000	1.66	104	20.0	Slight expansion
2100	0.62	39	11.2	Fine expansion; fine skin
2200	0.53	33	6.4	Fine expansion; fine skin
2300				

Recommendations: Fine lightweight aggregate possibilities.

ROTARY KILN TESTS:

Raw Material:

Screen Analysis (Crushed through a hammermill with 1½" screen)

Size		*Percent Retained*
—¾"	+ ½"	24.6
—½"	+ ⅜"	17.1
—⅜"	+ 4 mesh	27.5
—4 mesh	+ 8 mesh	25.2
—8 mesh	PAN	5.6
	TOTAL	100.0

Crushing loss (—4 mesh) 30.8%

Fragment shape: Tabular fragments

Firing Data:

Size range of feed: —¾ + 4 mesh   Pour weight of feed: 92.6 lb/ft³

Bloating temperature: 1970°F

Logging temperature* (*Nodules sticking together): 2010°F

Fired Material (all fired material crushed through a roll crusher)

Screen Analysis* (*ASTM Designation C 311-59T) in percentages by weight passing sieves:

Size designation	¾"	½"	⅜"	No. 4	No. 8	No. 16	No. 50	No. 100
Fine	—	—	100.0	77.8	—	21.1	7.6	5.3
Coarse	100.0	96.7	80.2	35.8	9.7	—	—	—

Loose pour weight* (*ASTM Designation C 311-59T):

Fine: 37.5 lb/ft³   Coarse: 35.0 lb/ft³

Color: Dark brown

COMMENTS: See Sample 137-8-3B. Excessive crushing loss of raw material; rounded lumps; flat plates; good pore structure; poor crushing characteristics.

Other Tests: Soluble Br. K. 1.10

Potential Uses: Preliminary bloating tests indicated lightweight aggregate potential. A composite of samples 137-8-3A and 137-8-3B was tested in the rotary kiln, but showed little potential. It is suggested that sample 137-8-3A, if tested alone in the rotary kiln, may produce a fair quality lightweight aggregate. There are no designated ceramic uses for this raw material.

CUMBERLAND COUNTY Middlesex Twp.

Sample Number
137-8-3B

Quadrangle: New Bloomfield 15′; Wertzville 7½′

Location: Quarry on the north side of Pa. Route 944 about 1.2 miles west of Donnellytown, Pa.

Geologic Unit: Martinsburg Formation, Ordovician

Description: Light-olive gray to olive gray shale is exposed in the northwest portion of the quarry. The shale fragments are pencil-shaped or elliptical in cross-section. Purple staining is common along fractures in addition to minor limonite staining. Folding is evident in this section of the quarry; bedding dips north in the vicinity of the sampling site, and further south a synclinal structure is exposed in the quarry wall.

Attitude of Bedding: No measurements were taken because of the folded condition of the rock.

Sampled Interval: Composite sample of 10 stratigraphic feet.

Type of Material: Shale

Ceramic Testing Laboratory: Norris

Chemical Analysis:

Analyst: Spectrochemical %

L.O.I. @ 1,000°C	5.15
H_2O Loss @ 110°C	0.59
Combined H_2O	NA
SiO_2	66.90
Al_2O_3	12.50
Fe_2O_3	3.99
FeO	3.47
CaO	0.44
MgO	1.73
CO_2	0.15
Na_2O	0.86
K_2O	3.95
TiO_2	0.94
P_2O_5	NA
MnO	NA
S (total)	0.02
C (total)	0.31

Mineralogy (X-ray):

	%	Accuracy (±%)
Quartz	33	5
Mica	40	7
Kaolinite	9	6
C-V-Mo	8	3
Feldspar	2	1

Remarks: Mineralogy indicates chemical analysis is low in Al_2O_3.

Other Properties:

pH: 8.65
P.C.E.: NA
Water of Plasticity (%): 22.4
Drying Shrinkage (%): 4.0
Dry Strength: Good
Drying Characteristics: Good; slight checking
Workability: Plastic; smooth; short-working

Slow-Firing Tests:

Temp. °F	*Color*	*Hardness*	*% Shk.*	*% Absorb.*	*% App. Por.*	*Approx. Sp. Gr.*
1800	Pale tan	Fair hard	4.0	5.5	—	2.63
1900	Tan	Hard	4.0	6.9	—	2.57
2000	Brown	Very hard	10.0	13.7	—	2.55
2100	Chocolate	Very hard	10.0	48.7	—	2.33
2200	Dark brown	Hard	0.0	31.2	—	0.86
2300	Dark brown	Hard	Expanded	27.8	—	0.76

Pyrometric cone equivalent: NA **Bloating test:** Positive

Remarks: Fair color; wavey surface; very high absorption; expansion. Addition of sodium silicate would lengthen the working period.

Bloating Tests (Quick-Firing):

Crushing characteristics: Good Particle size: —¾″ + ½″
Drying characteristics: Good Retention time: 15 minutes

Temp. °F	*Bulk Density*	*Lb/Ft³*	*% Absorb.*	*Remarks*
1800	—	—	—	
1900	—	—	—	
2000	1.73	108	14.3	Slight expansion
2100	0.76	47	11.3	Fine expansion; excellent skin
2200	0.50	31	6.4	Fine expansion; fine skin
2300				

Recommendations: Fine lightweight aggregate possibility.

ROTARY KILN TESTS:

Raw Material:

Screen Analysis (Crushed through a hammermill with 1½″ screen)

Size		*Percent Retained*
—¾″	+ ½″	24.6
—½″	+ ⅜″	17.1
—⅜″	+ 4 mesh	27.5
—4 mesh	+ 8 mesh	25.2
—8 mesh	PAN	5.6
	TOTAL	100.0

Crushing loss (—4 mesh) 30.8%

Fragment shape: Tabular fragments

Firing Data:

Size range of feed: ¾ + 4 mesh Pour weight of feed: 92.6 lb/ft³
Bloating temperature: 1970°F 44
Logging temperature* (*Nodules sticking together): 2010°F

Fired Material (all fired material crushed through a roll crusher)
Screen Analysis* (*ASTM Designation C 311-59T) in percentages by weight passing sieves:

Size designation	¾″	½″	⅜″	No. 4	No. 8	No. 16	No. 50	No. 100
Fine	—	—	100.0	77.8	—	21.1	7.6	5.3
Coarse	100.0	96.7	80.2	35.8	9.7	—	—	—

Loose pour weight* (*ASTM Designation C 311-59T):
Fine: 37.5 lb/ft³ Coarse: 35.0 lb/ft³
Color: Dark brown

COMMENTS: See Sample 137-8-3A. Excessive crushing loss of raw material; rounded lumps; flat plates; good pore structure; poor crushing characteristics.

Other Tests: Soluble Br. K. 0.47

Potential Uses: Outside pottery. Preliminary bloating tests indicated material has fine lightweight aggregate potential. A composite sample of samples 137-8-3A and 137-8-3B tested in the rotary kiln indicated the material has poor potential for lightweight aggregate. It is suggested that if sample 137-8-3B were tested alone, the material may produce a good quality lightweight aggregate.

CUMBERLAND COUNTY Hampden Twp.

Sample Number
137-9-2

Quadrangle: New Bloomfield 15′; Wertzville 7½′

Location: Exposure along the west side of Hunter Drive, immediately south of the intersection with Pa. Route 944. Hunter Drive is 0.2 mile east of the Saint Paul Church Cemetery on the south side of Pa. Route 944.

Geologic Unit: Martinsburg Formation, Ordovician

Description: Fissile to very thin-bedded shale is exposed for a distance of 175 feet along the roadside. The shale is almost yellow-gray to pale olive with a few grayish red (10 R 4/2) beds. Mica flakes are scattered throughout the shale, and iron oxide staining is common along cleavage, fractures, and bedding planes. The shale is moderately to intensely weathered. The height of the exposure is about 10 feet.

Sampled Interval: Composite sample of the northern 100 feet of the exposure.
Type of Material: Shale

Ceramic Testing Laboratory: Norris

Chemical Analysis:

Analyst: Spectrochemical

	%
L.O.I. @ 1,000°C	4.71
H_2O Loss @ 110°C	1.00
Combined H_2O	NA
SiO_2	64.50
Al_2O_3	15.50
Fe_2O_3	5.69
FeO	1.94
CaO	0.28
MgO	0.93
CO_2	0.13
Na_2O	1.65
K_2O	3.77
TiO_2	0.94
P_2O_5	NA
MnO	NA
S (total)	$>$ 0.03
C (total)	0.09

Mineralogy (X-ray):

	%	Accuracy (±%)
Quartz	29	8
Mica	46	10
Kaolinite	7	5
C-V-Mo	10	3
Feldspar	2	1

Remarks: Mineralogy indicates chemical analysis is low in Al_2O_3

Other Properties:

pH: 7.60
P.C.E.: NA
Water of Plasticity (%): 20.0
Drying Shrinkage (%): NA
Dry Strength: Good
Drying Characteristics: Fair; checking
Workability: Mealy; smooth; short-working

Slow-Firing Tests:

Temp. °F	Color	Hardness	% Shk.	% Absorb.	% App. Por.	Approx. Sp. Gr.
1800	Tan	Fair hard	2.0	5.3	—	2.49
1900	Light brown	Fair hard	5.0	6.1	—	2.49
2000	Brown	Hard	5.0	7.7	—	2.49
2100	Chocolate	Very hard	10.0	18.5	—	2.45
2200	Dark brown	Steel hard	10.0	45.0	—	2.42
2300						

Pyrometric cone equivalent: NA **Bloating test:** Negative

Remarks: Fair color; checking; wavey surface; high absorption.

Bloating Tests (Quick-Firing): NA

Other Tests: Soluble Br. K. 0.50

Potential Uses: No designated ceramic use.

CUMBERLAND COUNTY Silver Spring Twp.

Sample Number
137-9-4

Quadrangle: New Bloomfield 15′; Wertzville 7½′

Location: Road cut on the east side of a north-south macadam road, 0.2 mile directly south of Wertzville, Pa.

Geologic Unit: Martinsburg Formation, Ordovician

Description: Dusky yellow (5 Y 6/4), light-olive brown (5 Y 5/6), to moderate olive brown (5 Y 4/4), thin bedded shale is exposed intermittently along the roadway for a distance of about 250 feet. Weathering of the shale is moderate to severe. Beds range in thickness from ¼ inch up to several inches. Fragments are usually pencil-shaped or tabular and measure from less than one inch up to four inches in length. Iron oxide staining is common. The maximum height of the exposure is about 6 feet.

Attitude of Bedding: Folded, with bedding horizontal to steeply dipping to the south.

Sampled Interval: Composite of entire exposure.

Type of Material: Shale

Ceramic Testing Laboratory: Tuscaloosa

Chemical Analysis:

Analyst: Conwell	%
L.O.I. @ 1,000°C	6.25
H_2O Loss @ 110°C	1.34
Combined H_2O	4.21
SiO_2	55.61
Al_2O_3	20.22
Fe_2O_3	7.57

Mineralogy (X-ray):

	%	Accuracy (±%)
Quartz	28	7
Mica	51	8
Kaolinite	0	—
C-V-Mo	14	3
Feldspar	2	1
Remarks:		

Chemical Analysis:

Analyst: Conwell	%
FeO	1.30
CaO	0.40
MgO	1.73
CO_2	0.06
Na_2O	0.68
K_2O	2.84
TiO_2	0.85
P_2O_5	NA
MnO	NA
S (total)	0.04
C (total)	0.74

Other Properties:

pH: 4.60
P.C.E.: NA
Water of Plasticity (%): 16.0
Drying Shrinkage (%): 0.0
Dry Strength: Low
Drying Characteristics: Satisfactory
Workability: Mealy; low plasticity

Slow-Firing Tests:

Temp. °F	Color	Hardness	% Shk.	% Absorb.	% App. Por.	Approx. Sp. Gr.
1800	Tan	Moh's 3	0.0	16.5	—	1.82
1900	Tan	Moh's 3	0.0	14.5	—	1.85
2000	Dark tan	Moh's 4	2.5	12.7	—	2.01
2100	Light red	Moh's 7	5.0	5.7	—	2.25
2200	Dark red	Moh's 7+	10.0	2.5	—	2.35
2300	Dark brown	Moh's 7+	10.0	1.6	—	2.28
2400						

Pyrometric cone equivalent: NA **Bloating test:** Negative

Remarks: Short working; develops fair dark red; a tendency to dunt is indicated.

Other Tests: None

Potential Uses: Face brick; quarry tile.

CUMBERLAND COUNTY Middlesex Twp.

Sample Number
138-2-6

Quadrangle: Carlisle 15′; Mechanicsburg 7½′

Location: Quarry on the east side of an undesignated road, 300 feet south of Heberling School. The site is in the extreme northwest corner of the Mechanicsburg 7½′ Quadrangle.

Geologic Unit: Martinsburg Formation, Ordovician

Description: The sample of shale and graywacke was collected from bedrock on the quarry floor. Although shale predominates, graywacke is present in 2 inch thick beds in the extreme southern part of the quarry. The shale alternates between medium gray (fresh, N6) to medium dark gray (weathered, N5) and bi-colored olive gray (fresh, 5 Y 5/1) to medium yellow-brown (weathered, 1 YR/2). The medium gray shale breaks into pencil-like fragments; the bi-colored variety breaks into chippy fragments. The quarry is about 200 feet long and reaches a maximum height of 6 feet.

Attitude of Bedding: Bedding and cleavage attitudes nearly identical: N45E, 65S.

Sampled Interval: Composite sample taken every few feet across the quarry floor.

Type of Material: Shale

Ceramic Testing Laboratory: Tuscaloosa

Chemical Analysis:

Analyst: Conwell	%
L.O.I. @ 1,000°C	5.65
H_2O Loss @ 110°C	0.69
Combined H_2O	4.51
SiO_2	60.46
Al_2O_3	17.43
Fe_2O_3	5.90
FeO	1.37
CaO	0.30
MgO	2.61
CO_2	0.00
Na_2O	0.51
K_2O	2.84
TiO_2	0.78
P_2O_5	NA
MnO	NA
S (total)	None
C (total)	0.62

Mineralogy (X-ray):

	%	Accuracy (±%)
Quartz	28	5
Mica	56	8
Kaolinite	4	3
C-V-Mo	6	3
Feldspar	1	1

Remarks: Mineralogy indicates chemical analysis is low in K_2O.

Other Properties:

pH: 6.90
P.C.E.: NA
Water of Plasticity (%): 18.7
Drying Shrinkage (%): 2.5
Dry Strength: Low
Drying Characteristics: No defects
Workability: Gritty; low plasticity

Slow-Firing Tests:

Temp. °F	*Color*	*Hardness*	*% Shk.*	*% Absorb.*	*% App. Por.*	*Approx. Sp. Gr.*
1800	Tan	Moh's 2	2.5	15.7	28.7	1.83
1900	Light brown	Moh's 3	5.0	13.0	25.1	1.93
2000	Brown	Moh's 4	7.5	7.1	15.0	2.11
2100	Dark brown	Moh's 5	10.0	1.4	3.1	2.19
2200	—	—	Expanded	—	—	—
2300						

Pyrometric cone equivalent: NA **Bloating test:** Positive

Remarks: Poor color and low green strength for building brick use.

Bloating Tests (Quick-Firing):

Crushing characteristics: Platy and angular
Drying characteristics: NA
Particle size: ¾" lumps
Retention time: 15 minutes

Temp. °F	*Bulk Density*	*Lb/Ft³*	*% Absorb.*	*Remarks*
1800	—	—	—	
1900	2.26	141.0	1.4	No expansion
2000	0.79	49.3	8.9	Good pore structure
2100	0.79	49.3	6.8	Good pore structure; vitreous
2200				
2300				

Recommendations: Promising raw material for lightweight aggregate; a trial run in rotary kiln should be made.

ROTARY KILN TESTS:

Raw Material:

Screen Analysis (Crushed through a hammermill with 1½" screen)

Size		Percent Retained
—¾"	+ ½"	31.1
—½"	+ ⅜"	15.7
—⅜"	+ 4 mesh	26.6
—4 mesh	+ 8 mesh	6.6
—8 mesh	PAN	20.0
	TOTAL	100.0

Crushing loss (—4 mesh) 26.6%

Fragment shape: Angular

Firing Data:

Size range of feed: —¾ + 4 mesh Pour weight of feed: 84.0 lb/ft^3

Bloating temperature: 2020°F

Logging temperature* (*Nodules sticking together): 2070°F

Fired Material (all fired material crushed through a roll crusher)

Screen Analysis* (*ASTM Designation C 311-59T) in percentages by weight passing sieves:

Size designation	¾"	½"	⅜"	No. 4	No. 8	No. 16	No. 50	No. 100
Fine	—	—	100.0	33.6	—	17.4	5.0	3.0
Coarse	100.0	80.0	50.0	10.0	4.0	—	—	—

Loose pour weight* (*ASTM Designation C 311-59T):

Fine: 55.0 lb/ft^3 Coarse: 52.5 lb/ft^3

Color: Tan

COMMENTS: Best potential for lightweight aggregate; angular fragments; excellent pore structure; good crushing.

Other Tests: Not effervescent in HCl.

Potential Uses: Best potential for lightweight aggregate. Should fire to "MW" face brick specifications at about 1950°F.

CUMBERLAND COUNTY Dickinson Twp.

Sample Number

138-7-4

Quadrangle: Carlisle 15'; Mt. Holly Springs 7½'

Location: Abandoned quarry on the Lloyd Herman Farm about 0.6 mile north-northwest of Goodyear, Pa., and west of Pa. Route 34.

Geologic Unit: Metarhyolite, Precambrian

Description: A varicolored schist in metarhyolite exposed in an excavation measuring about 175 feet by 150 feet in plan. A minor amount of quartz is present among schist fragments on the dumps.

Attitude of Bedding: Obscured. Schistosity: N20E, 35S (average)

Sampled Interval: Grab sample of schist from the dumps.

Type of Material: Schist

Ceramic Testing Laboratory: Norris

Chemical Analysis:

Analyst: Spectrochemical

	%
L.O.I. @ 1,000°C	2.33
H_2O Loss @ 110°C	0.04
Combined H_2O	NA
SiO_2	67.00
Al_2O_3	18.30
Fe_2O_3	4.06
FeO	0.01
CaO	0.02
MgO	0.56
CO_2	0.33
Na_2O	0.43
K_2O	6.80
TiO_2	0.42
P_2O_5	NA
MnO	NA
S (total)	0.02
C (total)	0.09

Mineralogy (X-ray):

	%	Accuracy (±%)
Quartz	32	10
Mica	62	10
Kaolinite	0	—
C-V-Mo	0	—
Feldspar	2	1

Remarks: Mineralogy indicates chemical analysis is low in Al_2O_3.

Other Properties:

pH: 7.70
P.C.E.: NA
Water of Plasticity (%): 36.2
Drying Shrinkage (%): 0.0
Dry Strength: Fair
Drying Characteristics: Fair; slight warping
Workability: Plastic; smooth; long-working

Slow-Firing Tests:

Temp. °F	*Color*	*Hardness*	*% Shk.*	*% Absorb.*	*% App. Por.*	*Approx. Sp. Gr.*
1800	Buff	Crumbled in water				
1900	Buff	Soft	0.0	2.9	—	2.26
2000	Light tan	Soft	0.0	3.7	—	2.28
2100	Light tan	Fair hard	3.5	3.7	—	2.28
2200	Gray-tan	Hard	9.5	3.9	—	2.27
2300	Gray	Steel hard	15.0	4.8	—	2.36

Pyrometric cone equivalent: NA **Bloating test:** Positive

Remarks: Too soft, high silica.

Bloating Tests (Quick-Firing):

Crushing characteristics: Fair, shaly
Drying characteristics: Good
Particle size: —¾" + ½"
Retention time: 15 minutes

Temp. °F	*Bulk Density*	*Lb/Ft³*	*% Absorb.*	*Remarks*
1800	—	—	—	
1900	—	—	—	
2000	2.85	178	4.4	No expansion
2100	1.69	105	53.6	Slight expansion
2200	1.89	118	27.1	Slight expansion
2300				

Recommendations: Too heavy for lightweight aggregate possibilities.

Other Tests: Soluble Br. K. 1.60

Potential Uses: No designated ceramic use.

CUMBERLAND COUNTY East Pennsboro Twp.

Sample Number
147-7-1

Quadrangle: Harrisburg 15′; Harrisburg West 7½′

Location: Road cut along the north side of Pa. Route 944 about 0.2 mile west of Enola, Pa.

Geologic Unit: Martinsburg Formation, Ordovician

Description: Olive gray (5 Y 4/1), very thin-bedded to fissile, slightly to moderately weathered shale is exposed for a distance of 150 feet along the road cut. Silty shale beds 2 to 3 inches thick are interbedded with the shale. Iron staining is common along bedding planes. The exposure is 10 feet high.

Attitude of Bedding: N65E, vertical

Sampled Interval: Composite of eastern 100 feet of the exposure.

Type of Material: Shale

Ceramic Testing Laboratory: Norris

Chemical Analysis:

Analyst: Spectrochemical

	%
L.O.I. @ 1,000°C	5.15
H_2O Loss @ 110°C	0.53
Combined H_2O	NA
SiO_2	67.60
Al_2O_3	12.00
Fe_2O_3	4.04
FeO	0.18
CaO	0.61
MgO	1.52
CO_2	0.95
Na_2O	1.26
K_2O	3.80
TiO_2	0.82
P_2O_5	NA
MnO	NA
S (total)	0.04
C (total)	0.44

Mineralogy (X-ray):

	%	Accuracy (±%)
Quartz	37	5
Mica	34	6
Kaolinite	10	7
C-V-Mo	9	3
Feldspar	4	2

Remarks: Mineralogy indicates chemical analysis is low in Al_2O_3.

Other Properties:

pH: 8.50
P.C.E.: NA
Water of Plasticity (%): 22.4
Drying Shrinkage (%): 2.0
Dry Strength: Good
Drying Characteristics: Good, slightly warped
Workability: Plastic; smooth; long-working

Slow-Firing Tests:

Temp. °F	*Color*	*Hardness*	*% Shk.*	*% Absorb.*	*% App. Por.*	*Approx. Sp. Gr.*
1800	Tan	Fair hard	2.0	4.4	—	2.47
1900	Light brown	Fair hard	3.0	5.7	—	2.42
2000	Brown	Hard	5.5	8.5	—	2.43
2100	Chocolate	Very hard	10.0	34.1	—	2.36
2200	Dark brown	Hard	Expanded	37.1	—	1.23
2300	Dark brown	Hard	Expanded	29.8	—	0.66

Pyrometric cone equivalent: NA **Bloating test:** Positive

Remarks: Fair color; warping; high absorption; expansion.

Bloating Tests (Quick-Firing):

Crushing characteristics: Fair-shaly Particle size: —¾″ + ½″

Drying characteristics: Good Retention time: 15 minutes

Temp. °F	*Bulk Density*	*Lb/Ft³*	*% Absorb.*	*Remarks*
1800	—	—		
1900	—	—		
2000	1.39	87	10.7	Layered expansion
2100	0.81	51	10.9	Layered expansion, good
2200	0.65	41	9.9	Layered expansion, sticky
2300				

Recommendations: Good lightweight aggregate possibility.

ROTARY KILN TESTS:

Raw Material:

Screen Analysis (Crushed through a hammermill with 1½″ screen)

Size		*Percent Retained*
—¾″	+ ½″	22.0
—½″	+ ⅜″	10.4
—⅜	+ 4 mesh	32.9
—4 mesh	+ 8 mesh	18.9
—8 mesh	PAN	15.8
	TOTAL	100.0

Crushing loss (—4 mesh) 34.7%

Fragment shape: Thin plates; few angular lumps.

Firing Data:

Size range of feed: —¾ + 4 mesh Pour weight of feed: 83.8 lb/ft³

Bloating temperature: 1930°F

Logging temperature* (*Nodules sticking together): 1980°F

Fired Material (all fired material crushed through a roll crusher)

Screen Analysis* (*ASTM Designation C 311-59T) in percentages by weight passing sieves:

Size designation	¾″	½″	⅜″	No. 4	No. 8	No. 16	No. 50	No. 100
Fine	—	—	100.0	64.8	—	11.5	4.2	3.0
Coarse	100.0	92.5	81.4	47.1	15.5	—	—	—

Loose pour weight* (*ASTM Designation C 311-59T):

Fine: 43.1 lb/ft³ Coarse: 44.4 lb/ft³

Color: Light brown

COMMENTS: Excessive crushing loss of raw material; short firing range; undesirable fragment shape of fired product (thin plates). Mostly thin plates; few rounded lumps; fair pore structure; poor crushing characteristics.

Other Tests: Soluble Br. K. 1.25
Slightly effervescent (carbonate) in HCl.

Potential Uses: Outside pottery. Preliminary bloating tests suggest possibilities for lightweight aggregate; rotary kiln tests do not indicate this material would be very good as raw material for lightweight aggregate. At best it might be useful for fair quality lightweight aggregate.

CUMBERLAND COUNTY Upper Allen Twp.

Sample Number
148-1-2

Quadrangle: New Cumberland 15′; Lemoyne 7½′

Location: Road cut on the east side of U. S. Route 15, about 0.25 miles south of the Pennsylvania Turnpike overpass.

Geologic Unit: Martinsburg Formation, Ordovician

Description: Medium to dark gray, thin-bedded shale with a few white quartz veinlets, parallel to cleavage is exposed in a 25 foot-high road cut. The upper portion of the slope is composed of highly-weathered shale fragments; relatively unweathered shale is exposed in the lower part of the road cut.

Attitude of Bedding: Obscured. Cleavage: N50-60E, vertical

Sampled Interval: Composite sample of the northern 150 feet of the exposure.

Type of Material: Shale

Ceramic Testing Laboratory: Norris

Chemical Analysis:

Analyst: Spectrochemical %

L.O.I @ 1,000°C	4.62
H_2O Loss @ 110°C	1.71
Combined H_2O	NA
SiO_2	68.30
Al_2O_3	14.00
Fe_2O_3	6.56
FeO	ND
CaO	$>$ 0.05
MgO	1.04
CO_2	0.22
Na_2O	0.51
K_2O	3.90
TiO_2	0.92
P_2O_5	NA
MnO	NA
S (total)	$>$ 0.02
C (total)	0.12

Mineralogy (X-ray):

	%	*Accuracy (±%)*
Quartz	50	10
Mica	35	12
Kaolinite	0	—
C-V-Mo	9	3
Feldspar	1	1

Remarks: Mineralogy indicates chemical analysis is low in Al_2O_3.

Other Properties:

pH: 8.00
P.C.E.: NA
Water of Plasticity (%): 28.6
Drying Shrinkage (%): 0.0
Dry Strength: Good
Drying Characteristics: Fair, slight warping; scum
Workability: Plastic; smooth; long-working

Slow-Firing Tests:

Temp. °F	Color	Hardness	% Shk.	% Absorb.	% App. Por.	Approx. Sp. Gr.
1800	Tan	Soft	0.0	5.9	—	2.52
1900	Tan	Fair hard	0.0	4.6	—	2.50
2000	Light brown	Hard	6.5	7.6	—	2.48
2100	Light brown	Hard	6.5	8.1	—	2.45
2200	Dark brown	Very hard	6.5	78.3	—	1.82
2300	Black	Very hard	Expanded	20.5	—	0.89

Pyrometric cone equivalent: NA **Bloating test:** Positive

Remarks: Poor color, warping, uneven color due to heavy scum, slight effervescence (carbonates).

Bloating Tests (Quick-Firing):

Crushing characteristics: Fair, shaly Particle size: —¾″ + ½″

Drying characteristics: Good Retention time: 15 minutes

Temp. °F	Bulk Density	Lb/Ft^3	% Absorb.	Remarks
1800	—	—	—	
1900	—	—	—	
2000	1.93	120	17.5	Very little expansion
2100	1.30	81	10.9	Fair expansion
2200	0.79	49	8.7	Fine expansion—good skin
2300				

Recommendations: Good lightweight aggregate possibilities.

ROTARY KILN TESTS:

Raw Material:

Screen Analysis (Crushed through a hammermill with 1½″ screen)

Size		Percent Retained
—¾″	+ ½″	20.3
—½″	+ ⅜″	17.2
—⅜″	+ 4 mesh	38.2
—4 mesh	+ 8 mesh	11.7
—8 mesh	PAN	12.6
	TOTAL	100.0

Crushing loss (—4 mesh) 34.3%

Fragment shape: Thin plates and angular fragments.

Firing Data:

Size range of feed: —¾ + 4 mesh Pour weight of feed: 93.9 lb/ft^3

Bloating temperature: 2070°F

Logging temperature* (*Nodules sticking together): 2080°F

Fired Material (all fired material crushed through a roll crusher)

Screen Analysis* (*ASTM Designation C 311-59T) in percentages by weight passing sieves:

Size designation	3/4"	1/2"	3/8"	No. 4	No. 8	No. 16	No. 50	No. 100
Fine	—	—	100.0	48.0	—	6.0	4.3	3.9
Coarse	100.0	58.0	36.0	19.0	12.8	—	—	—

Loose pour weight* (*ASTM Designation C 311-59T):

Fine: 46.3 lb/ft^3 Coarse: 37.0 lb/ft^3

Color: Brown

COMMENTS: Excessive crushing loss of raw material; short firing range; laminar; angular lumps; fair pore structure; satisfactory crushing characteristics.

Other Tests: Soluble Br. K. 4.00

Potential Uses: Preliminary bloating tests indicate this material would have good lightweight aggregate potential. Rotary kiln testing does not confirm this. Fair quality lightweight aggregate might be produced from this material.

DAUPHIN COUNTY Swatara Twp.

Sample Number
147-8-4

Quadrangle: Harrisburg 15′; Harrisburg East 7½′

Location: On the north slope of a hill approximately 600 feet south of Pa. Route 441, 1,200 feet south of the Dauphin County Home.

Geologic Unit: Martinsburg Formation, Ordovician

Description: The exposure is medium olive gray (4 Y 5/1) phyllitic shale which weathers to a pale-grayish orange (10 YR 8/4) and is overlain by 8 feet of overburden. The phyllite foliae are ⅛ inch thick at the top of the sample interval, increasing to one inch in thickness at the base. Quartz veins, 2 to 3 inches thick are scattered throughout the shale. The Martinsburg Formation is underlain by a faulted sequence of Cambro-Ordovician rock.

Attitude of Bedding: Basically horizontal except at zone of contact with underlying carbonate rock.

Sampled Interval: Composite to semi-channel sample collected normal to bedding.

Type of Material: Shale

Ceramic Testing Laboratory: Tuscaloosa

Chemical Analysis:

Analyst: Conwell	%
L.O.I. @ 1,000°C	9.27
H_2O Loss @ 110°C	0.45
Combined H_2O	3.95
SiO_2	54.08
Al_2O_3	16.56
Fe_2O_3	3.30
FeO	1.80

Mineralogy (X-ray):

	%	Accuracy (±%)
Quartz	26	5
Mica	36	7
Kaolinite	8	6
C-V-Mo	9	3
Feldspar	1	1

Remarks: Moderate amount of carbonate present.

Chemical Analysis:

Analyst: Conwell

	%
CaO	8.06
MgO	2.34
CO_2	5.71
Na_2O	0.78
K_2O	2.02
TiO_2	0.70
P_2O_5	NA
MnO	NA
S (total)	None
C (total)	0.02

Other Properties:

pH: 9.00
P.C.E.: NA
Water of Plasticity (%): 21.5
Drying Shrinkage (%): 2.5
Dry Strength: Low
Drying Characteristics: Scum
Workability: Low plasticity

Slow-Firing Tests:

Temp. °F	*Color*	*Hardness*	*% Shk.*	*% Absorb.*	*% App. Por.*	*Approx. Sp. Gr.*
1800	Tan	Moh's 2	2.5	27.3	41.8	1.53
1900	Tan	Moh's 2	2.5	24.6	38.4	1.56
2000	Light brown	Moh's 3	5.0	21.0	34.9	1.66
2100	Brown	Moh's 4	10.0	1.9	3.9	2.03
2200	—	—	Expanded	—	—	—
2300						

Pyrometric cone equivalent: NA **Bloating test:** Negative

Remarks: Abrupt vitrification; may be limy.

Bloating Tests (Quick-Firing): NA

Other Tests: Highly effervescent with HCl.

Potential Uses: No designated ceramic use.

DAUPHIN COUNTY Susquehanna Twp.

Sample Number
147-8-6

Quadrangle: Harrisburg 15′; Harrisburg West 7½′

Location: An abandoned quarry approximately 1.2 miles north of the Farm Show Building, Harrisburg, Pa., in a field across the road from the north end of Waring's Wildwood Crest Public Golf Course, and east of Crooked Hill Road.

Geologic Unit: Martinsburg Formation, Ordovician

Description: Medium-dark gray (N4), thin-bedded (1/16 inch thick) shale that weathers to a moderate brown (5 YR ¾) color is exposed in the quarry. At the extreme northeast end of the quarry the shale is interbedded with a six inch thick dolomite (?). The exposure is 50 feet long and 10 feet high and is overlain by several feet of river-terrace sand and gravel.

Attitude of Bedding: Approximately vertical

Sampled Interval: Composite sample of the quarry.

Type of Material: Shale

Ceramic Testing Laboratory: Tuscaloosa

Chemical Analysis:

Analyst: Conwell

	%
L.O.I. @ 1,000°C	5.73
H_2O Loss @ 110°C	0.82
Combined H_2O	4.43
SiO_2	58.96
Al_2O_3	18.66
Fe_2O_3	4.69
FeO	2.59
CaO	0.60
MgO	2.39
CO_2	0.51
Na_2O_3	1.14
K_2O	2.81
TiO_2	0.70
P_2O_5	NA
MnO	NA
S (total)	0.18
C (total)	0.53

Mineralogy (X-ray):

	%	Accuracy (±%,
Quartz	29	7
Mica	40	8
Kaolinite	6	4
C-V-Mo	8	3
Feldspar	2	1

Remarks: Carbonate present

Other Properties:

pH: 5.90
P.C.E.: NA
Water of Plasticity (%): 17.9
Drying Shrinkage (%): 2.5
Dry Strength: Low
Drying Characteristics: No defects
Workability: Low plasticity

Slow-Firing Tests:

Temp. °F	*Color*	*Hardness*	*% Shk.*	*% Absorb.*	*% App. Por.*	*Approx. Sp. Gr.*
1800	Tan	Moh's 2	2.5	15.0	28.1	1.87
1900	Tan	Moh's 2	2.5	12.4	24.1	1.94
2000	Brown	Moh's 3	7.5	6.3	13.6	2.16
2100	Brown	Moh's 4	7.5	0.6	1.2	2.00
2200	—	—	Expanded	—	—	—
2300						

Pyrometric cone equivalent: NA **Bloating test:** Positive

Remarks: Not suitable for use in vitreous clay products; limy.

Bloating Tests (Quick-Firing):

Crushing characteristics: Angular Particle size: ¾" lumps
Drying characteristics: NA Retention time: 15 minutes

Temp. °F	*Bulk Density*	*Lb/Ft³*	*% Absorb.*	*Remarks*
1800	—	—	—	
1900	2.02	126.0	6.9	No expansion
2000	1.07	66.8	9.0	Laminar expansion
2100	0.68	42.4	13.3	Overfired vitreous
2200	—	—	—	
2300				

Recommendations: Marginal for lightweight aggregate (poor fragment shape); trial run in rotary kiln should be made.

ROTARY KILN TESTS:

Raw Material:

Screen Analysis (Crushed through a hammermill with 1½" screen)

Size		Percent Retained
—¾"	+ ½"	32.4
—½"	+ ⅜"	13.2
—⅜"	+ 4 mesh	26.2
—4 mesh	+ 8 mesh	9.1
—8 mesh	PAN	19.1
	TOTAL	100.0

Crushing loss (—4 mesh) 28.2%

Fragment shape: Angular and platy

Firing Data:

Size range of feed: —¾ + 4 mesh   Pour weight of feed: 84.0 lb/ft³

Bloating temperature: 2020°F

Logging temperature* (*Nodules sticking together): 2060°F

Fired Material (all fired material crushed through a roll crusher)

Screen Analysis* (*ASTM Designation C 311-59T) in percentages by weight passing sieves:

Size designation	¾"	½"	⅜"	No. 4	No. 8	No. 16	No. 50	No. 100
Fine	—	—	100.0	34.0	—	6.0	2.6	2.2
Coarse	100.0	82.0	54.0	10.0	4.4	—	—	—

Loose pour weight* (*ASTM Designation C 311-59T):

Fine: 47.5 lb/ft³   Coarse: 47.5 lb/ft³

Color: Dark brown

COMMENTS: Best potential for lightweight aggregate; angular fragments; good crushing; some large pores.

Other Tests: Slightly effervescent with HCl.

Potential Uses: Best potential for lightweight aggregate produced by rotary kiln methods.

Remarks: This exposure is thought to be either a worked out or temporarily abandoned shale pit of the Glen-Gery Brick Corp. It also may be a quarry for fill material.

DAUPHIN COUNTY Susquehanna Twp.

Sample Number

147-8-7

Quadrangle: Harrisburg 15′; Harrisburg West 7½′

Location: Road cut exposure on the east side of Crooked Hill Road approximately 125 feet north of intersection with Wildwood Road, or approximately 1.9 miles north of the Farm Show Building, Harrisburg, Pa.

Geologic Unit: Martinsburg Formation, Ordovician

Description: Medium-greenish gray (5 GY 5/1), thin-bedded (1/16 inch) shale, which weathers to a light-olive gray (5 Y 6/1), crops out in 10 foot high exposure for 100 feet along the road.

Attitude of Bedding: Obscure; cleavage (?): N70W, 50N

Sampled Interval: Composite sample of material taken every few inches across the outcrop.

Type of Material: Shale

Ceramic Testing Laboratory: Tuscaloosa

Chemical Analysis:

Analyst: Conwell	%
L.O.I. @ 1,000°C	6.03
H_2O Loss @ 110°C	1.66
Combined H_2O	5.24
SiO_2	56.30
Al_2O_3	20.01
Fe_2O_3	5.15
FeO	1.66
CaO	0.40
MgO	2.30
CO_2	0.11
Na_2O	0.68
K_2O	2.81
TiO_2	1.34
P_2O_5	NA
MnO	NA
S (total)	None
C (total)	0.34

Mineralogy (X-ray):

	%	Accuracy (±%)
Quartz	21	5
Mica	64	8
Kaolinite	0	—
C-V-Mo	9	3
Feldspar	1	1
Remarks:		

Other Properties:

pH: 6.70
P.C.E.: NA
Water of Plasticity (%): 18.7
Drying Shrinkage (%): 2.5
Dry Strength: Low
Drying Characteristics: No defects
Workability: Low plasticity

Slow-Firing Tests:

Temp. °F	*Color*	*Hardness*	*% Shk.*	*% Absorb.*	*% App. Por.*	*Approx. Sp. Gr.*
1800	Tan	Moh's 2	5.0	15.4	28.5	1.85
1900	Tan	Moh's 3	5.0	11.9	23.8	2.00
2000	Light brown	Moh's 4	10.0	5.2	11.8	2.26
2100	Brown	Moh's 5	12.5	0.6	1.4	2.41
2200			Expanded			
2300						

Pyrometric cone equivalent: NA **Bloating test:** Negative

Remarks: Poor color

Bloating Tests (Quick-Firing): NA

Other Tests: Not effervescent with HCl.

Potential Uses: Should fire to "MW" face brick specifications at about 1950°F.

DAUPHIN COUNTY Swatara Twp.

Sample Number
147-9-2

Quadrangle: Harrisburg 15′; Harrisburg East 7½′

Location: Road cut on the south side of U. S. Routes 322 and 422 immediately east of Patton Street, Chamber Hill, Pa. Sample was collected behind the "Soft Ice Cream" stand.

Geologic Unit: Martinsburg Formation, Ordovician

Description: The road cut exposes a medium greenish-gray (5 GY 5/1), blocky shale that weathers to grayish orange (10 YR 1/4) and reddish brown (10 R 4/6). The exposure is 170 feet long, 12 to 18 feet high, and is capped by 5 feet of overburden.

Attitude of Bedding: Essentially horizontal

Sampled Interval: Composite, randomly collected at both ends of the exposure.

Type of Material: Shale

Ceramic Testing Laboratory: Tuscaloosa

Chemical Analysis:

Analyst: Conwell	%
L.O.I. @ 1,000°C	5.90
H_2O Loss @ 110°C	0.34
Combined H_2O	5.81
SiO_2	55.52
Al_2O_3	22.46
Fe_2O_3	8.64
FeO	0.43
CaO	0.20
MgO	0.78
CO_2	0.14
Na_2O	0.54
K_2O	3.31
TiO_2	0.80
P_2O_5	NA
MnO	NA
S (total)	None
C (total)	0.01

Mineralogy (X-ray):

	%	*Accuracy (±%)*
Quartz	21	6
Mica	54	8
Kaolinite	13	7
C-V-Mo	6	3
Feldspar	1	1

Remarks:

Other Properties:

pH: 6.20
P.C.E.: NA
Water of Plasticity (%): 18.7
Drying Shrinkage (%): 2.5
Dry Strength: Low
Drying Characteristics: No defects
Workability: Low plasticity

Slow-Firing Tests:

Temp. °F	*Color*	*Hardness*	*% Shk.*	*% Absorb.*	*% App. Por.*	*Approx. Sp. Gr.*
1800	Tan	Moh's 2	2.5	25.1	38.9	1.55
1900	Tan	Moh's 2	2.5	24.1	38.3	1.59
2000	Light brown	Moh's 3	5.0	13.4	25.6	1.91
2100	Brown	Moh's 4	7.5	10.6	21.5	2.03
2200	Dark brown	Moh's 5	10.0	5.5	12.2	2.21
2300	Dark brown	Moh's 5	10.0	2.9	6.6	2.26

Pyrometric cone equivalent: NA **Bloating test:** Negative

Remarks:

Bloating Tests (Quick-Firing): NA

Other Tests: Not effervescent with HCl.

Potential Uses: Should fire to "SW" face brick specifications about 2150°F.

DAUPHIN COUNTY Swatara Twp.

Sample Number
147-9-3

Quadrangle: Harrisburg 15′; Harrisburg East 7½′

Location: Exposure on the south side of U. S. Routes 322 and 422, approximately one mile east of Patton Street, Chamber Hill, Pa. The outcrop was sampled behind the Texaco Station.

Geologic Unit: Martinsburg Formation, Ordovician

Description: The outcrop is fresh to slightly weathered, medium olive gray (5 Y 5/1), phyllitic shale that weathers to a light brown (5 YR 6/4). The exposure is approximately 65 feet long and 50 feet high, 20 feet of which is overburden.

Attitude of Bedding: Horizontal

Sampled Interval: Composite of the lower 20 feet of the stratigraphic sequence.

Type of Material: Shale

Ceramic Testing Laboratory: Tuscaloosa

Chemical Analysis:

Analyst: Conwell	%
L.O.I. @ 1,000°C	5.87
H_2O Loss @ 110°C	0.37
Combined H_2O	5.78
SiO_2	54.18
Al_2O_3	24.73
Fe_2O_3	4.91
FeO	3.10
CaO	0.20
MgO	1.73
CO_2	0.23
Na_2O	0.81
K_2O	2.83
TiO_2	0.92
P_2O_5	NA
MnO	NA
S (total)	0.01
C (total)	0.36

Mineralogy (X-ray):

	%	*Accuracy (±%)*
Quartz	20	5
Mica	45	6
Kaolinite	10	8
C-V-Mo	13	3
Feldspar	2	1

Remarks:

Other Properties:

pH: 6.80
P.C.E.: NA
Water of Plasticity (%): 19.1
Drying Shrinkage (%): 0.0
Dry Strength: Low
Drying Characteristics: No defects
Workability: Low plasticity

Slow-Firing Tests:

Temp. °F	*Color*	*Hardness*	*% Shk.*	*% Absorb.*	*% App. Por.*	*Approx. Sp. Gr.*
1800	Tan	Moh's 2	2.5	18.9	33.5	1.77
1900	Tan	Moh's 2	2.5	16.9	30.4	1.80
2000	Brown	Moh's 3	5.0	9.1	18.8	2.07
2100	Brown	Moh's 4	7.5	7.0	15.1	2.16
2200	Dark brown	Moh's 5	10.0	4.2	9.5	2.25
2300	Dark brown	Moh's 5	10.0	1.6	3.6	2.26

Pyrometric cone equivalent: NA **Bloating test:** Negative

Remarks:

Bloating Tests (Quick-Firing):

Other Tests: Not effervescent with HCl.

Potential Uses: Should fire to "SW" face brick specifications at about 2050°F.

DAUPHIN COUNTY Lower Paxton Twp.

Sample Number
147-9-5

Quadrangle: Harrisburg 15'; Harrisburg East 7½'

Location: Road cut exposure at the T-intersection of Locust Lane and Nye Road. The outcrop is on the east side of Nye Road and was sampled immediately north of the intersection.

Geologic Unit: Martinsburg Formation, Ordovician

Description: The outcrop is composed of dark-greenish gray (5 GY 4/1), moderately weathered shale that weathers to olive gray (5 Y 4/1). The exposure is 270 feet long and 10 feet high.

Attitude of Bedding: Obscure; cleavage: N90E, 40-70S

Sampled Interval: Composite sample taken approximately every foot, approximately normal to bedding.

Type of Material: Shale

Ceramic Testing Laboratory: Tuscaloosa

Chemical Analysis:

Analyst: Conwell	%
L.O.I. @ 1,000°C	4.84
H_2O Loss @ 110°C	0.33
Combined H_2O	4.67
SiO_2	63.00
Al_2O_3	16.05
Fe_2O_3	4.61
FeO	2.66
CaO	0.30
MgO	2.48
CO_2	0.34
Na_2O	1.08
K_2O	2.69
TiO_2	0.85
P_2O_5	NA
MnO	NA
S (total)	None
C (total)	0.32

Mineralogy (X-ray):

	%	Accuracy (±%)
Quartz	31	8
Mica	50	10
Kaolinite	6	5
C-V-Mo	6	3
Feldspar	2	1

Remarks:

Other Properties:

pH: 5.50

P.C.E.: NA

Water of Plasticity (%): 16.5

Drying Shrinkage (%): 0.0

Dry Strength: Low

Drying Characteristics: No defects

Workability: Low plasticity

Slow-Firing Tests:

Temp. °F	Color	Hardness	% Shk.	% Absorb.	% App. Por.	Approx. Sp. Gr.
1800	Tan	Moh's 2	5.0	14.5	27.6	1.90
1900	Tan	Moh's 3	5.0	11.7	23.0	1.97
2000	Brown	Moh's 4	7.5	3.8	8.6	2.25
2100	Brown	Moh's 5	10.0	1.8	4.2	2.32
2200	—	—	Expanded	—	—	—
2300						

Pyrometric cone equivalent: NA **Bloating test:** Positive

Remarks: Poor color.

Bloating Tests (Quick-Firing):

Crushing characteristics: Angular Particle size: ¾″ lumps

Drying characteristics: NA Retention time: 15 minutes

Temp. °F	Bulk Density	Lb/Ft³	% Absorb.	Remarks
1800	—	—	—	
1900	1.62	101.1	9.3	No expansion
2000	1.72	107.3	8.6	No expansion
2100	0.96	59.9	11.1	Overfired—vitreous
2200				
2300				

Recommendations: Marginal for lightweight aggregate (poor fragment shape); trial run in rotary kiln should be made.

ROTARY KILN TESTS:

Raw Material:

Screen Analysis (Crushed through a hammermill with 1½″ screen)

Size		Percent Retained
—¾″	+ ½″	26.7
—½″	+ ⅜″	17.9
—⅜″	+ 4 mesh	30.4
—4 mesh	+ 8 mesh	6.5
—8 mesh	PAN	18.5
	TOTAL	100.0

Crushing loss (—4 mesh) 25.0%

Fragment shape: Thin plates

Firing Data:

Size range of feed: —¾ + 4 mesh Pour weight of feed: 76.0 lb/ft³

Bloating temperature: 1990°F

Logging temperature* (*Nodules sticking together): 2060°F

Fired Material (all fired material crushed through a roll crusher)
Screen Analysis* (*ASTM Designation C 311-59T) in percentages by weight passing sieves:

Size designation	¾"	½"	⅜"	No. 4	No. 8	No. 16	No. 50	No. 100
Fine	—	—	100.0	63.0	—	21.5	8.5	5.5
Coarse	100.0	75.0	49.0	5.8	1.4	—	—	—

Loose pour weight* (*ASTM Designation C 311-59T):
Fine: 45.0 lb/ft^3 Coarse: 37.5 lb/ft^3
Color: Dark brown

COMMENTS: Marginal for lightweight aggregate. Undesirable fragment shape of fired product. Angular and tabular fragments; fair pore structure; good crushing.

Other Tests: Not effervescent with HCl.

Potential Uses: Should fire to "MW" face brick specification at about 1925°F. Rotary kiln tests indicate that marginal to good quality lightweight aggregate might be produced from this raw material.

DAUPHIN COUNTY Swatara Twp.

Sample Number
148-3-6

Quadrangle: New Cumberland 15'; Steeltown 7½'

Location: Exposure about 200 feet east of Pa. Route 283 and 0.1 mile north of the intersection of Pa. Routes 283 and 441.

Geologic Unit: Martinsburg Formation, Ordovician

Description: The exposure is divided by a fault zone that trends north-northwest. A moderately to highly weathered phyllite located at the north end of the exposure was sampled. Quartz veins are present in the vicinity of the fault zone. The sampled portion of the exposure is 30 feet long and 8 feet high. The basal 7 feet are grayish orange (10 YR 7/4): the upper 5 feet are light brownish gray (5 YR 6/1).

Attitude of Bedding: Approximate strike: E-W, Dip: 10S and 30S, respectively at the north and south ends of the sample area.

Sampled Interval: Composite sample of every few inches for 12 stratigraphic feet.

Type of Material: Shale

Ceramic Testing Laboratory: Tuscaloosa

Chemical Analysis:

Analyst: Conwell	%
L.O.I. @ 1,000°C	5.30
H_2O Loss @ 110°C	0.70
Combined H_2O	4.95
SiO_2	56.77
Al_2O_3	21.93
Fe_2O_3	7.68

Mineralogy (X-ray):

	%	*Accuracy (±%)*
Quartz	25	5
Mica	46	6
Kaolinite	9	7
C-V-Mo	13	3
Feldspar	2	1
Remarks:		

Chemical Analysis:

Analyst: Conwell

	%
FeO	0.72
CaO	0.10
MgO	2.02
CO_2	0.00
Na_2O	0.03
K_2O	3.50
TiO_2	0.99
P_2O_5	NA
MnO	NA
S (total)	0.02
C (total)	0.16

Other Properties:

pH: 5.40
P.C.E.: NA
Water of Plasticity (%): 25.4
Drying Shrinkage (%): 0.0
Dry Strength: Low
Drying Characteristics: No defects
Workability: Low plasticity

Slow-Firing Tests:

Temp. °F	*Color*	*Hardness*	*% Shk.*	*% Absorb.*	*% App. Por.*	*Approx. Sp. Gr.*
1800	Tan	Moh's 2	2.5	26.7	41.7	1.56
1900	Tan	Moh's 2	2.5	25.8	40.5	1.57
2000	Light brown	Moh's 3	5.0	17.1	30.8	1.80
2100	Brown	Moh's 4	7.5	13.7	26.2	1.91
2200	Red brown	Moh's 5	10.0	6.4	14.0	2.18
2300	Dark brown	Moh's 5	10.0	1.0	2.3	2.25

Pyrometric cone equivalent: NA **Bloating test:** Negative

Bloating Tests (Quick-Firing): NA

Other Tests: Not effervescent with HCl.

Potential Uses: Should fire to "SW" face brick specifications at about 2150°F.

Remarks: The phyllitic shale north and south of the fault zone is reasonably dissimilar, especially in color; the exposure was sampled on this basis as two separate samples; i.e., Sample 148-3-6 north of the fault zone and Sample 148-3-7 south of the fault zone.

DAUPHIN COUNTY Swatara Twp.

Sample Number
148-3-7

Quadrangle: New Cumberland 15′; Steelton 7½′

Location: Exposure about 200 feet east of Pa. Route 283, and 0.1 mile north of the intersection of Pa. Routes 283 and 441.

Geologic Unit: Martinsburg Formation, Ordovician

Description: The exposure is divided by a fault zone which trends north-northwest. The sample was taken from the south end of the exposure and is composed of moderately to highly weathered phyllite. Quartz veins are present in the vicinity of the fault zone. Fresh phyllite is medium greenish-gray (5 GY 5/1); weathered it is pale-yellow orange (10 YR 8/6).

Attitude of Bedding: Slump and structural complexities account for variable dip and strike of bedding.

Sampled Interval: Composite sample collected parallel to the base of the exposure.

Type of Material: Shale, phyllitic

Ceramic Testing Laboratory: Tuscaloosa

Chemical Analysis:

Analyst: Conwell	%
L.O.I. @ 1,000°C	5.65
H_2O Loss @ 110°C	0.72
Combined H_2O	5.63
SiO_2	60.16
Al_2O_3	20.03
Fe_2O_3	7.07
FeO	0.50
CaO	0.10
MgO	1.17
CO_2	0.00
Na_2O	0.01
K_2O	3.29
TiO_2	0.88
P_2O_5	NA
MnO	NA
S (total)	0.15
C (total)	0.16

Mineralogy (X-ray):

	%	Accuracy (±%)
Quartz	32	5
Mica	42	6
Kaolinite	19	7
C-V-Mo	0	—
Feldspar	2	1

Remarks:

Other Properties:

pH: 6.40
P.C.E.: NA
Water of Plasticity (%): 29.0
Drying Shrinkage (%): 0.0
Dry Strength: Low
Drying Characteristics: No defects
Workability: Low plasticity

Slow-Firing Tests:

Temp. °F	*Color*	*Hardness*	*% Shk.*	*% Absorb.*	*% App. Por.*	*Approx. Sp. Gr.*
1800	Yellow	Moh's 2	2.5	28.3	42.2	1.49
1900	Yellow	Moh's 2	5.0	27.3	42.0	1.54
2000	Light brown	Moh's 3	7.5	14.2	27.0	1.90
2100	Brown	Moh's 4	7.5	10.7	21.7	2.03
2200	Dark brown	Moh's 5	10.0	5.0	11.1	2.21
2300	Red brown	Moh's 5	12.5	2.2	4.9	2.22

Pyrometric cone equivalent: NA **Bloating test:** Negative

Bloating Tests (Quick-Firing): NA

Other Tests: Not effervescent with HCl.

Potential Uses: Should fire to "MW" face brick specifications at about 2100°F.

Remarks: See Sample 148-3-6 for complementary notes.

DAUPHIN COUNTY **East Hanover Twp.**

Sample Number
157-5-6

Quadrangle: Hummelstown 15'; Hummelstown 7½'

Location: Road cut about 0.5 mile southwest of Grantville, Pa., along the northwest side of U. S. Route 22, 0.2 mile west of the Pa. Route 743-U. S. Route 22 intersection.

Geologic Unit: Martinsburg Formation, Ordovician

Description: Greenish gray (5 GY 6/1) and medium-light to medium-dark gray (N 7 to N 4), thin-bedded shales are exposed for a distance of 2100 feet along the northwestern side of U. S. Route 22. At the southwestern end of the exposure, red shales are interbedded with gray shale. The beds never exceed several inches in thickness. The shale is slightly to moderately weathered. The height of the exposure is approximately 15 feet.

Attitude of Bedding: N60E, essentially vertical

Sampled Interval: Composite sample of 300 feet of shale at the northeastern end of the exposure.

Type of Material: Shale

Ceramic Testing Laboratory: Norris

Chemical Analysis:

Analyst: Spectrochemical %

L.O.I. @ 1,000°C	19.54
H_2O Loss @ 110°C	0.23
Combined H_2O	NA
SiO_2	51.30
Al_2O_3	3.00
Fe_2O_3	1.70
FeO	1.13
CaO	13.90
MgO	7.16
CO_2	17.77
Na_2O	0.46
K_2O	1.07
TiO_2	0.29
P_2O_5	NA
MnO	NA
S (total)	0.02
C (total)	0.10

Mineralogy (X-ray):

	%	Accuracy (±%)
Quartz	47	5
Mica	20	6
Kaolinite	9	7
C-V-Mo	7	3
Feldspar	2	1

Remarks: Mineralogy indicates chemical analysis is low in Al_2O_3. Moderate amount of carbonate present.

Other Properties:

pH: 9.65
P.C.E.: NA
Water of Plasticity (%): 17.0
Drying Shrinkage (%): 1.0
Dry Strength: Good
Drying Characteristics: Fair; warping; scum.
Workability: Short working; fatty; fine grit

Slow-Firing Tests:

Temp. °F	*Color*	*Hardness*	*% Shk.*	*% Absorb.*	*% App. Por.*	*Approx. Sp. Gr.*
1800	Dark ivory	Fair hard	4.0	3.0	—	2.74
1900	Ivory	Fair hard	4.0	3.0	—	2.67
2000	Ivory	Fair hard	4.0	2.8	—	2.64
2100	Cream	Hard	4.0	2.7	—	2.63
2200	Spotted buff	Very hard	4.0	2.4	—	2.67
2300	Melted	—	4.0	—	—	—

Pyrometric cone equivalent: NA **Bloating test:** Negative

Remarks: Light color; warping; scum; rather soft; spotted. Addition of alkali and barium salt would improve ceramic properties.

Bloating Tests (Quick-Firing): NA

Other Tests: Soluble Br. K. 2.00

Potential Uses: Possible face brick by using alkali and barium salt.

DAUPHIN COUNTY East Hanover Twp.

Sample Number
157-5-7

Quadrangle: Hummelstown 15′; Hummelstown 7½′

Location: Outcrop on the east side of Pa. Route 743, about 1.75 miles south of the intersection with U. S. Route 22.

Geologic Unit: Martinsburg Formation, Ordovician

Description: A greenish-gray (5 GY 6/1), moderately to highly weathered, shale is exposed in a shale bank 7 feet high. The shale weathers grayish red (5 R 4/2) to tan from south to north along the outcrop. Sampling was started about 50 feet from the south end of the outcrop and was continued for 150 feet northward.

Attitude of Bedding: Approximate strike: E-W; Dip 45-80S.

Sampled Interval: Composite sample taken every two feet along the outcrop.

Type of Material: Shale

Ceramic Testing Laboratory: Tuscaloosa

Chemical Analysis:

Analyst: Conwell	%
L.O.I. @ 1,000°C	4.62
H_2O Loss @ 110°C	1.12
Combined H_2O	3.88
SiO_2	65.62
Al_2O_3	14.52
Fe_2O_3	6.20
FeO	0.36
CaO	0.20
MgO	2.85
CO_2	0.56
Na_2O	0.62
K_2O	2.40
TiO_2	0.60
P_2O_5	NA
MnO	NA
S (total)	None
C (total)	0.03

Mineralogy (X-ray):

	%	*Accuracy (±%)*
Quartz	37	5
Mica	48	6
Kaolinite	0	—
C-V-Mo	8	3
Feldspar	2	1

Remarks:

Other Properties:

pH: 6.80
P.C.E.: NA
Water of Plasticity (%): 20.5
Drying Shrinkage (%): 0.0
Dry Strength: Low
Drying Characteristics: No defects
Workability: Low plasticity

Slow-Firing Tests:

Temp. °F	Color	Hardness	% Shk.	% Absorb.	% App. Por.	Approx. Sp. Gr.
1800	Light brown	Moh's 2	5.0	12.9	24.8	1.92
1900	Light brown	Moh's 3	5.0	11.6	23.0	1.98
2000	Brown	Moh's 4	7.5	4.2	9.2	2.20
2100	Brown	Moh's 5	7.5	2.6	5.7	2.18
2200	—	—	Expanded	—	—	—
2300						

Pyrometric cone equivalent: NA **Bloating test:** Negative

Remarks: Poor color

Bloating Tests (Quick-Firing): NA

Other Tests: Not effervescent with HCl.

Potential Uses: Should fire to "SW" face brick specifications at about 1950°F.

DAUPHIN COUNTY East Hanover Twp.

Sample Number
157-8-8

Quadrangle: Hummelstown 15′; Hummelstown 7½′

Location: Outcrop north-northeast of Hershey, Pa., in the northwest quadrant of the intersection of Pa. Route 743 and Swatara Creek.

Geologic Unit: Martinsburg Formation, Ordovician

Description: Olive gray (5 Y 5/1) shale that weathers to a greenish gray (5 GY 6/1) is exposed in an outcrop 210 feet long and 3 to 20 feet high, the middle portion of which is covered. Sample 157-8-8 was collected from the outcrop north of the covered interval.

Attitude of Bedding: Obscure; cleavage: E-W, vertical

Sampled Interval: Composite; sample collected every one to two feet normal to dip.

Type of Material: Shale, phyllitic

Ceramic Testing Laboratory: Tuscaloosa

Chemical Analysis:

Analyst: Conwell	%
L.O.I. @ 1,000°C	5.48
H_2O Loss @ 110°C	0.51
Combined H_2O	6.24
SiO_2	50.71
Al_2O_3	24.56
Fe_2O_3	3.46
FeO	6.91
CaO	0.20
MgO	2.02

Mineralogy (X-ray):

	%	Accuracy (±%)
Quartz	17	5
Mica	30	6
Kaolinite	35	7
C-V-Mo	11	3
Feldspar	2	1
Remarks:		

Chemical Analysis:

Analyst: Conwell	%
CO_2	0.35
Na_2O	1.21
K_2O	2.23
TiO_2	1.06
P_2O_5	NA
MnO	NA
S (total)	None
C (total)	0.08

Other Properties:

pH: 8.20
P.C.E.: NA
Water of Plasticity (%): 15.8
Drying Shrinkage (%): 2.5
Dry Strength: Low
Drying Characteristics: No defects
Workability: Low plasticity

Slow Firing Tests:

Temp. °F	*Color*	*Hardness*	*% Shk.*	*% Absorb.*	*% App. Por.*	*Approx. Sp. Gr.*
1800	Light brown	Moh's 2	2.5	11.2	22.8	2.04
1900	Light brown	Moh's 2	5.0	11.9	24.9	2.08
2000	Brown	Moh's 3	7.5	7.2	16.3	2.27
2100	Dark brown	Moh's 4	7.5	2.1	5.2	2.49
2200	Dark brown	Moh's 5	10.0	1.0	2.5	2.50
2300	Dark brown	Moh's 6	10.0	1.2	3.0	2.47

Pyrometric cone equivalent: NA **Bloating test:** Negative

Remarks: Low green strength.

Bloating Tests (Quick-Firing): NA

Other Tests: Not effervescent with HCl.

Potential Uses: Should fire to "SW" face brick specifications at about 2000°F.

Remarks: Sample 157-8-9 was collected from the portion of the outcrop south of the covered interval.

DAUPHIN COUNTY East Hanover Twp.

Sample Number
157-8-9

Quadrangle: Hummelstown 15′; Hummelstown 7½′

Location: Outcrop north-northeast of Hershey, Pa., in the northwest quadrant of the intersection of Pa. Route 743 and Swatara Creek.

Geologic Unit: Martinsburg Formation, Ordovician

Description: Fresh, medium light gray (N5 to N6) shale that weathers to greenish tan is exposed in an outcrop 210 feet long and 3 to 20 feet high, the middle portion of which is covered. Sample 157-8-9 was collected south of the covered interval.

Attitude of Bedding: Obscure: E-W, 45S.

Sampled Interval: Composite sample; collected every 1 to 2 feet normal to dip.

Type of Material: Phyllitic shale

Ceramic Testing Laboratory: Tuscaloosa

Chemical Analysis:

Analyst: Conwell	%
L.O.I. @ 1,000°C	4.80
H_2O Loss @ 110°C	0.28
Combined H_2O	4.60
SiO_2	58.50
Al_2O_3	19.76
Fe_2O_3	2.76
FeO	4.90
CaO	1.11
MgO	2.69
CO_2	0.62
Na_2O	0.89
K_2O	2.50
TiO_2	0.70
P_2O_5	NA
MnO	NA
S (total)	None
C (total)	0.33

Mineralogy (X-ray):

	%	Accuracy (±%)
Quartz	26	5
Mica	23	6
Kaolinite	28	7
C-V-Mo	11	3
Feldspar	2	1

Remarks:

Other Properties:

pH: 6.20
P.C.E.: NA
Water of Plasticity (%): 17.6
Drying Shrinkage (%): 2.5
Dry Strength: Low
Drying Characteristics: Scumming
Workability: Low plasticity

Slow-Firing Tests:

Temp. °F	Color	Hardness	% Shk.	% Absorb.	% App. Por.	Approx. Sp. Gr.
1800	Tan	Moh's 2	2.5	14.2	27.1	1.91
1900	Tan	Moh's 2	2.5	14. 8	28.0	1.89
2000	Brown	Moh's 3	5.0	10.1	20.8	2.06
2100	Dark brown	Moh's 4	10.0	1.2	2.8	2.37
2200	Dark brown	Moh's 5	7.5	3.2	5.9	1.83
2300	—	—	Expanded	—	—	—

Pyrometric cone equivalent: NA **Bloating test:** Positive

Remarks: Not suitable for use in vitreous clay products. Abrupt vitrification.

Bloating Tests (Quick-Firing):

Crushing characteristics: Angular Particle size: ¾″ Lumps
Drying characteristics: NA Retention time: 15 minutes

Temp. °F	Bulk Density	Lb/Ft³	% Absorb.	Remarks
1800	—	—	—	
1900	2.20	137.3	5.6	No expansion
2000	1.65	103.0	8.6	No expansion
2100	0.78	48.7	8.4	Fair pore structure; vitreous
2200				
2300				

Recommendations: Marginal for lightweight aggregate (short range); trial run in rotary kiln should be made.

ROTARY KILN TESTS:

Raw Material:

Screen Analysis (Crushed through a hammermill with 1½" screen)

Size		Percent Retained
—¾"	+ ½"	28.7
—½"	+ ⅜"	12.2
—⅜"	+ 4 mesh	24.2
—4 mesh	+ 8 mesh	7.9
—8 mesh	PAN	27.0
	TOTAL	100.0

Crushing loss (—4 mesh) 34.9%

Fragment shape: Thin plates

Firing Data:

Size range of feed: —¾ + 4 mesh Pour weight of feed: 80.0 lb/ft^3

Bloating temperature: 2020°F

Logging temperature* (*Nodules sticking together): 2040°F

Fired Material (all fired material crushed through a roll crusher)

Screen Analysis* (*ASTM Designation C 311-59T) in percentages by weight passing sieves:

Size designation	¾"	½"	⅜"	No. 4	No. 8	No. 16	No. 50	No. 100
Fine	—	—	100.0	84.4	—	48.8	36.8	21.6
Coarse	100.0	83.0	65.0	30.0	12.0	—	—	—

Loose pour weight* (*ASTM Designation C 311-59T):

Fine: 55.0 lb/ft^3 Coarse: 45 lb/ft^3

Color: Brown

COMMENTS: Short firing range; tabular flat plates; poor crushing; fair pore structure. Not promising for lightweight aggregate.

Other Tests: Slightly effervescent with HCl.

Potential Uses: Rotary kiln tests indicate this is not promising as raw material for lightweight aggregate production.

Remarks: Sample 157-8-9 was collected from the portion of the outcrop north of the covered interval.

FRANKLIN COUNTY Warren Twp.

Sample Number

99-9-1

Quadrangle: Needmore 15'

Location: Quarry on east side of Pa. Route 456 about 0.5 mile north of the town of Sylvan, Pa.

Geologic Unit: Mahantango Formation, Devonian

Description: Predominantly olive-gray (5 Y 4/1), medium-bedded, non-fissile shale is exposed in a quarry 30′(H) x 75′(W) x 100′(L). The beds range from several inches to about 2 feet in thickness. The shale is moderately weathered with yellow-brown iron oxide stains common along fractures. Fragments are irregular, tabular, or pencil-like in shape and break easily.

Attitude of Bedding: Approximately N80W, 5S

Sampled Interval: Channel sample taken along a stratigraphic interval of 10 feet.

Type of Material: Shale

Ceramic Testing Laboratory: Tuscaloosa

Chemical Analysis:

Analyst: Conwell	%
L.O.I. @ 1,000°C	4.92
H_2O Loss @ 110°C	0.76
Combined H_2O	5.29
SiO_2	62.38
Al_2O_3	18.90
Fe_2O_3	3.80
FeO	2.88
CaO	1.51
MgO	1.70
CO_2	0.14
Na_2O	0.68
K_2O	2.50
TiO_2	0.62
P_2O_5	NA
MnO	NA
S (total)	0.02
C (total)	0.12

Mineralogy (X-ray):

	%	Accuracy (±%)
Quartz	31	7
Mica	50	8
Kaolinite	7	6
C-V-Mo	6	3
Feldspar	1	1

Remarks:

Other Properties:

pH: 7.00
P.C.E.: NA
Water of Plasticity (%): 16.9
Drying Shrinkage (%): 2.5
Dry Strength: Low
Drying Characteristics: Satisfactory
Workability: Mealy; low plasticity

Slow-Firing Tests:

Temp. °F	*Color*	*Hardness*	*% Shk.*	*% Absorb.*	*% App. Por.*	*Approx. Sp. Gr.*
1800	Buff	Moh's 2	2.5	18.0	—	1.83
1900	Buff	Moh's 3	5.0	15.4	—	1.91
2000	Light red	Moh's 4	5.0	11.4	—	1.95
2100	Dark red	Moh's 5	7.5	5.7	—	2.20
2200	Overfired	—	—	—	—	—
2300	Melted	—	—	—	—	—

Pyrometric cone equivalent: NA **Bloating test:** Positive

Remarks: Short working; fires to fair dark red.

Bloating Tests (Quick-Firing):

Crushing characteristics: Angular — Particle size: —¾″ + ½″
Drying characteristics: NA — Retention time: 15 minutes

Temp. °F	Bulk Density	Lb/Ft³	% Absorb.	Remarks
1800				
1900				
2000	1.38	86	4.72	Rich brown
2100	1.34	84	5.11	Good pore structure
2200	0.72	45	4.50	Thin vitreous shell
2300				

Recommendations: Trial run in rotary kiln.

ROTARY KILN TESTS:

Raw Material:

Screen Analysis (Crushed through a hammermill with 1½" screen)

Size		Percent Retained
—¾"	+ ½"	32.9
—½"	+ ⅜"	20.8
—⅜"	+ 4 mesh	28.6
—4 mesh	+ 8 mesh	5.9
—8 mesh	PAN	11.8
	TOTAL	100.0

Crushing loss (—4 mesh) 17.7%

Fragment shape: Angular

Firing Data:

Size range of feed: —¾ + 4 mesh Pour weight of feed: 94.8 lb/ft³

Bloating temperature: 2000°F

Logging temperature* (*Nodules sticking together): 2040°F

Fired Material (all fired material crushed through a roll crusher)

Screen Analysis* (*ASTM Designation C 311-59T) in percentages by weight passing sieves:

Size designation	¾"	½"	⅜"	No. 4	No. 8	No. 16	No. 50	No. 100
Fine	—	—	100.0	44.8	—	5.5	1.9	1.5
Coarse	100.0	98.7	91.4	40.4	10.8	—	—	—

Loose pour weight* (*ASTM Designation C 311-59T):

Fine: 51.6 lb/ft³ Coarse: 47.2 lb/ft³

Color: Light brown

COMMENTS: Undesirable fragment shape of fired product (thin plates); thin plates and angular lumps; good pore structure; poor crushing characteristics.

Other Tests: None

Potential Uses: Rotary kiln tests suggest this material may make a fair lightweight aggregate.

Remarks: Intermittent quarrying of material for fill.

FRANKLIN COUNTY Warren Twp.

Sample Number
99-12-2

Quadrangle: Hancock 15′; Cherry Run 7½′

Location: Road cut exposure along east side of Pa. Route 456 about 0.3 mile northwest of Yeakle Mill, Pa.

Geologic Unit: Mahantango Formation, Devonian

Description: Olive-gray, fissile to thin-bedded shales are exposed for a distance of about 350 feet along the roadway. The thickest bed measures approximately 5 inches. Sub-spheroidal concretions(?) commonly occur in the shale and measure as much as a foot along the maximum axis. They often exhibit concentric weathering halos. The shale fragments are tabular, platy, pencil-like, or irregular. Iron staining is common along fracture surfaces. The height of the exposure is between 10 and 20 feet.

Attitude of Bedding: N40E, 25S

Sampled Interval: Channel sample taken along a stratigraphic interval of 15 feet.

Type of Material: Shale

Ceramic Testing Laboratory: Tuscaloosa

Chemical Analysis:

Analyst: Conwell	%
L.O.I. @ 1,000°C	4.90
H_2O Loss @ 110°C	0.45
Combined H_2O	5.15
SiO_2	62.90
Al_2O_3	16.77
Fe_2O_3	3.35
FeO	3.67
CaO	1.92
MgO	1.94
CO_2	0.58
Na_2O	0.94
K_2O	2.40
TiO_2	0.99
P_2O_5	NA
MnO	NA
S (total)	0.17
C (total)	0.50

Mineralogy (X-ray):

	%	*Accuracy (±%)*
Quartz	38	8
Mica	36	8
Kaolinite	11	7
C-V-Mo	8	3
Feldspar	2	1

Remarks:

Other Properties:

pH: 7.00
P.C.E.: NA
Water of Plasticity (%): 15.9
Drying Shrinkage (%): 0.0
Dry Strength: Low
Drying Characteristics: Satisfactory
Workability: Gritty; low plasticity

Slow-Firing Tests:

Temp. °F	*Color*	*Hardness*	*% Shk.*	*% Absorb.*	*% App. Por.*	*Approx. Sp. Gr.*
1800	Buff	Moh's 2	2.5	17.2	—	1.83
1900	Buff	Moh's 3	2.5	17.1	—	1.82
2000	Light brown	Moh's 4	5.0	14.1	—	1.92
2100	Red brown	Moh's 5	5.0	7.0	—	2.05
2200	Overfired	—	—	—	—	—
2300	Melted	—	—	—	—	—

Pyrometric cone equivalent: NA **Bloating test:** Positive

Remarks: Short working; fires to fair red brown.

Bloating Tests (Quick-Firing):

Crushing characteristics: Laminar Particle size: —¾" + ½"

Drying characteristics: NA Retention time: 15 minutes

Temp. °F	*Bulk Density*	*Lb/Ft³*	*% Absorb.*	*Remarks*
1800				
1900				
2000				
2100	1.04	65	10.1	Dark brown
2200	1.06	66	5.2	Laminar prominent
2300	0.74	46	8.5	Thin vitreous shell

Recommendations: Trial run in rotary kiln should be made.

ROTARY KILN TESTS:

Raw Material:

Screen Analysis (Crushed through a hammermill with 1½" screen)

Size		*Percent Retained*
—¾"	+ ½"	39.1
—½"	+ ⅜"	21.0
—⅜"	+ 4 mesh	23.5
—4 mesh	+ 8 mesh	7.0
—8 mesh	PAN	9.4
	TOTAL	100.0

Crushing loss (—4 mesh) 16.4%

Fragment shape: Angular

Firing Data:

Size range of feed: —¾ + 4 mesh. Pour weight of feed: 88.9 lb/ft³

Bloating temperature: 1940°F

Logging temperature* (*Nodules sticking together): 2000°F

Fired Material (all fired material crushed through a roll crusher)

Screen Analysis* (*ASTM Designation C 311-59T) in percentages by weight passing sieves:

Size designation	¾"	½"	⅜"	No. 4	No. 8	No. 16	No. 50	No. 100
Fine	—	—	100.0	40.0	—	7.6	4.6	3.8
Coarse	100.0	66.0	35.0	16.0	3.0	—	—	—

Loose pour weight* (*ASTM Designation C 311-59T):

Fine: 37.9 lb/ft³ Coarse: 37.0 lb/ft³

Color: Light brown

COMMENTS: Best potential for lightweight aggregate product; rounded lumps; good pore structure; satisfactory crushing characteristics.

Other Tests: None

Potential Uses: Best potential for lightweight aggregate according to rotary kiln tests.

FRANKLIN COUNTY Metal Twp.

Sample Number
109-2-2

Quadrangle: Mercersburg 15′; McConnellsburg 7½′

Location: Exposure along the west side of Pa. Route 75, approximately 2 miles north of Richmond Furnace, Pa.

Geologic Unit: Reedsville Formation, Ordovician

Description: Dark gray (N3) to brownish black (5 YR 2/1), calcareous, fissile to thin-bedded, carbonaceous shales are exposed intermittently for a distance of 500 feet along the road. The shale is moderately to severely weathered with yellow-gray rims very common on the weathered rock surfaces. Fossiliferous shales (with graptolites? trilobite?, and brachiopods, and others) occur in the northernmost 20 feet of the exposure. The height of the exposure averages about 10 feet.

Attitude of Bedding: N45E, 45S (general attitude)

Sampled Interval: Composite of the outcrop

Type of Material: Shale

Ceramic Testing Laboratory: Tuscaloosa

Chemical Analysis:

Analyst: Conwell	%
L.O.I. @ 1,000°C	17.78
H_2O Loss @ 110°C	0.65
Combined H_2O	4.90
SiO_2	46.82
Al_2O_3	9.33
Fe_2O_3	1.29
FeO	1.51
CaO	19.15
MgO	1.06
CO_2	13.82
Na_2O	0.51
K_2O	1.54
TiO_2	0.44
P_2O_5	NA
MnO	NA
S (total)	0.11
C (total)	1.01

Mineralogy (X-ray):

	%	Accuracy (±%)
Quartz	27	8
Mica	30	10
Kaolinite	8	6
C-V-Mo	0	
Feldspar	1	1

Remarks: High carbonate content.

Other Properties:

pH: 7.00
P.C.E.: NA
Water of Plasticity (%): 16.1
Drying Shrinkage (%): 0.0
Dry Strength: Low
Drying Characteristics: Satisfactory
Workability: Gritty; low plasticity

Slow-Firing Tests:

Temp. °F	Color	Hardness	% Shk.	% Absorb.	% App. Por.	Approx. Sp. Gr.
1800	Salmon	Moh's 3	—	36.2	—	1.40
1900	Salmon	Moh's 4	—	36.8	—	1.37
2000	Salmon	Moh's 4	—	37.8	—	1.36
2100	Melted	—	—	—	—	—
2200						
2300						

Pyrometric cone equivalent: NA **Bloating test:** Negative

Bloating Tests (Quick-Firing): NA

Other Tests: Not effervescent with HCl.

Potential Uses: No designated ceramic use.

Remarks: Field relations suggest that the shale may be too weathered for use as a raw material for making lightweight aggregate.

FRANKLIN COUNTY Metal Twp.

Sample Number
109-2-3

Quadrangle: Mercersburg 15′; McConnellsburg 7½′

Location: Cut on west side of highway along Pa. Route 75 about 1.3 miles south of Richmond Furnace, Pa.

Geologic Unit: Reedsville Formation, Ordovician

Description: Medium dark gray (N4) to dark greenish-gray (5 GY 4/1) shales are exposed along both sides of the highway for a distance of about 1500 feet. The moderately to severely weathered shale ranges in color from gray orange to medium brown on the exposed rock surfaces. Shale fragments on the slope are small and pencil-like in shape. The exposure is 10 to 15 feet high.

Attitude of Bedding: N5E, 52N

Sampled Interval: Grab sample of southern 1000 feet of exposure.

Type of Material: Shale

Ceramic Testing Laboratory: Tuscaloosa

Chemical Analysis:

Analyst: Conwell	%
L.O.I. @ 1,000°C	5.56
H_2O @ 110°C	0.94
Combined H_2O	4.66
SiO_2	63.40
Al_2O_3	17.51
Fe_2O_3	3.65
FeO	1.30
CaO	1.51
MgO	1.88
CO_2	0.35
Na_2O	0.59
K_2O	3.16
TiO_2	0.84
P_2O_5	NA
MnO	NA
S (total)	0.08
C (total)	0.35

Mineralogy (X-ray):

	%	*Accuracy* (±%)
Quartz	33	7
Mica	52	8
Kaolinite	4	2
C-V-Mo	6	3
Feldspar	1	1

Remarks:

Other Properties:

pH: 6.20
P.C.E.: NA
Water of Plasticity (%): 19.7
Drying Shrinkage (%): 2.5
Dry Strength: Fair
Drying Characteristics: Satisfactory
Workability: Gritty; low plasticity

Slow-Firing Tests:

Temp. °F	Color	Hardness	% Shk.	% Absorb.	% App. Por.	Approx. Sp. Gr.
1800	Tan	Moh's 3	5.0	19.9	—	1.74
1900	Tan	Moh's 4	5.0	16.0	—	1.84
2000	Buff	Moh's 4	7.5	12.1	—	1.97
2100	Brown	Moh's 6	10.0	4.6	—	2.20
2200	Overfired	—	—	—	—	—
2300	Overfired	—	—	—	—	—

Pyrometric cone equivalent: NA **Bloating test:** Negative

Remarks: Color marginal; overfired at 2200°F.

Bloating Tests (Quick-Firing): NA

Other Tests: None

Potential Uses: Face brick

Remarks: Field relations of the shale suggests that it may not be a suitable raw material for lightweight aggregate.

FRANKLIN COUNTY Peters Twp.

Sample Number

109-5-1

Quadrangle: Mercersburg 15′; McConnellsburg 7½′

Location: West of Fort Loudon on the south side of U. S. Route 30 just east of its intersection with Pa. Route 75.

Geologic Unit: Reedsville Formation, Ordovician

Description: A predominantly dark gray (N3) to grayish black (N2), medium-bedded, calcareous shale is exposed in a road cut for a distance of several hundred feet. The beds range from 2 to 6 inches in thickness. Most of the exposed rock consists of fragments tabular to pencil-like. Weathering is slight with about one half of the rock fragments exhibiting a thin, light tan, weathered rim. Pyrite occurs in some of the rock layers, and joint surfaces are usually coated with quartz or calcite. The height of the exposure is about 40 feet.

Attitude of Bedding: Strike N7°E; dip: to the south

Sampled Interval: Grab sample taken for entire exposure.

Type of Material: Shale

Ceramic Testing Laboratory: Tuscaloosa

Chemical Analysis:

Analyst: Conwell	%
L.O.I. @ 1,000°C	26.05
H_2O Loss @ 110°C	0.31
Combined H_2O	2.69
SiO_2	31.62
Al_2O_3	6.48
Fe_2O_3	1.51
FeO	0.65

Mineralogy (X-ray):

	%	Accuracy (±%)
Quartz		
Mica		
Kaolinite		
C-V-Mo		
Feldspar		

Remarks: High carbonate content; mica > quartz; trace of feldspar

Chemical Analysis:

Analyst: Conwell	%
CaO	31.05
MgO	1.34
CO_2	23.62
Na_2O	0.05
K_2O	1.20
TiO_2	0.33
P_2O_5	NA
MnO	NA
S (total)	0.12
C (total)	0.69

Other Properties:

pH: 7.40
P.C.E.: NA
Water of Plasticity (%): 12.5
Drying Shrinkage (%): 0.0
Dry Strength: Low
Drying Characteristics: Satisfactory
Workability: Gritty; non-plastic

Slow-Firing Tests:

Temp. °F	*Color*	*Hardness*	*% Shk.*	*% Absorb.*	*% App. Por.*	*Approx. Sp. Gr.*
1800	Salmon	Moh's 1	0.0	46.7	—	1.22
1900	Salmon	Moh's 1	0.0	51.4	—	1.17
2000	Salmon	Moh's 2	0.0	54.5	—	1.12
2100	Cream	Moh's 3	0.0	51.2	—	1.15
2200	Ivory	Moh's 3	0.0	38.5	—	1.35
2300	Olive	Moh's 4	0.0	27.5	—	1.49

Pyrometric cone equivalent: NA **Bloating test:** Negative

Bloating Tests (Quick-Firing): NA

Other Tests: Highly effervescent with HCl.

Potential Uses: No designated ceramic use.

FRANKLIN COUNTY Antrim Twp.

Sample Number
109-6-4A

Quadrangle: Mercersburg 15′; Williamson 7½′

Location: The sample was collected along a road cut on the northeast side of the secondary road trending northwest from Stone Bridge, Pa. The sampling site is about 0.2 mile from Stone Bridge, Pa. and 2.1 miles east of Williamson, Pa.

Geologic Unit: Martinsburg Formation, Ordovician

Description: Dark yellow-brown (10 YR 4/2) to medium dark gray, moderately weathered, thin-bedded, silty shales predominate in the southern part of the road cut. The beds range in thickness from ¼ inch to about 6 inches. To the northwest the rock becomes finer-grained and changes to a soft, olive gray (5 Y 4/1) to dark yellow-brown (10 YR 4/2), fissile to thin-bedded shale. The exposure is about 500 feet long and reaches heights of about 15 feet.

Attitude of Bedding: N15E, 78S

Sampled Interval: The Sample A represents the northernmost 150 feet of the exposure. Composite sample.

Type of Material: Shale

Ceramic Testing Laboratory: Tuscaloosa

Chemical Analysis:

Analyst: Conwell	%
L.O.I. @ 1,000°C	5.74
H_2O Loss @ 110°C	0.58
Combined H_2O	4.37
SiO_2	62.38
Al_2O_3	14.85
Fe_2O_3	4.22
FeO	2.88
CaO	3.23
MgO	2.54
CO_2	1.45
Na_2O	1.40
K_2O	2.21
TiO_2	0.77
P_2O_5	NA
MnO	NA
S (total)	0.04
C (total)	0.56

Mineralogy (X-ray):

	%	*Accuracy* (±%)
Quartz	33	7
Mica	46	10
Kaolinite	7	4
C-V-Mo	6	3
Feldspar	2	1

Remarks:

Other Properties:

pH: 6.80
P.C.E.: NA
Water of Plasticity (%): 16.2
Drying Shrinkage (%): 2.5
Dry Strength: Low
Drying Characteristics: Satisfactory
Workability: Gritty, low plasticity

Slow-Firing Tests:

Temp. °F	*Color*	*Hardness*	*% Shk.*	*% Absorb.*	*% App. Por.*	*Approx. Sp. Gr.*
1800	Light brown	Moh's 2	2.5	20.6	—	1.72
1900	Light brown	Moh's 2	2.5	19.2	—	1.76
2000	Brown	Moh's 3	2.5	16.1	—	1.83
2100	Dark brown	Moh's 6	5.0	7.1	—	2.06
2200	Overfired	—	—	—	—	—
2300	Overfired	—	—	—	—	—

Pyrometric cone equivalent: NA **Bloating test:** Negative

Remarks: Poor color

Bloating Tests (Quick-Firing): NA

Other Tests: Slightly effervescent with HCl.

Potential Uses: No designated ceramic use.

FRANKLIN COUNTY Antrim Twp.

Sample Number
109-6-4B

Quadrangle: Mercersburg 15′; Williamson 7½′

Location: The sampling site is a road cut about 0.2 mile from Stone Bridge, Pa. and 2.1 miles east of Williamson, Pa. along the northeast side of a secondary road trending northwest from Stone Bridge, Pa.

Geologic Unit: Martinsburg Formation, Ordovician

Description: Dark yellow-brown (10 YR 4/2) to medium dark gray, moderately weathered, thin-bedded, silty shales predominate in the southern part of the road cut. The beds range in thickness from ¼ inch to 6 inches. To the northwest the rock becomes finer-grained and changes to a soft, fissile to thin-bedded shale. The exposure is about 500 feet long and reaches heights of about 15 feet.

Attitude of Bedding: N15E, 78S

Sampled Interval: Sample B represents the southern 100 feet of the exposure. Composite sample.

Type of Material: Shale

Ceramic Testing Laboratory: Tuscaloosa

Chemical Analysis:

Analyst: Conwell	%
L.O.I. @ 1,000°C	5.12
H_2O Loss @ 110°C	1.24
Combined H_2O	4.36
SiO_2	60.53
Al_2O_3	17.21
Fe_2O_3	4.71
FeO	1.94
CaO	1.02
MgO	2.63
CO_2	0.26
Na_2O	0.94
K_2O	2.88
TiO_2	0.96
P_2O_5	NA
MnO	NA
S (total)	0.12
C (total)	0.07

Mineralogy (X-ray):

	%	*Accuracy* (±%)
Quartz	29	6
Mica	52	7
Kaolinite	5	4
C-V-Mo	8	3
Feldspar	2	1

Remarks:

Other Properties:

pH: 6.40
P.C.E.: NA
Water of Plasticity (%): 14.9
Drying Shrinkage (%): 2.5
Dry Strength: Low
Drying Characteristics: Satisfactory
Workability: Gritty; non-plastic

Slow-Firing Tests:

Temp. °F	*Color*	*Hardness*	*% Shk.*	*% Absorb.*	*% App. Por.*	*Approx. Sp. Gr.*
1800	Tan	Moh's 2	2.5	17.4	—	1.81
1900	Tan	Moh's 3	5.0	14.2	—	1.91
2000	Light brown	Moh's 5	5.0	10.2	—	2.01
2100	Brown	Moh's 7	7.5	4.3	—	2.21
2200	Overfired	—	—	—	—	—
2300	Overfired	—	—	—	—	—

Pyrometric cone equivalent: NA **Bloating test:** Positive

Remarks: Short working; color poor.

Bloating Tests (Quick-Firing):

Crushing characteristics: Laminar Particle size: —¾" + ½"

Drying characteristics: NA Retention time: 15 minutes

Temp. °F	Bulk Density	Lb/Ft^3	% Absorb.	Remarks
1800	—	—	—	
1900	—	—	—	Bulk density too high.
2000	1.86	116	4.7	
2100	1.50	94	5.1	
2200	1.71	107	2.8	
2300				

Recommendations: Not promising for lightweight aggregate.

Other Tests: None

Potential Uses: No designated ceramic use.

FRANKLIN COUNTY St. Thomas Twp.

Sample Number

109-6-5

Quadrangle: Mercersburg 15′; Williamson 7½′

Location: Southeast of Williamson, Pa., and about 0.1 mile southeast of Black Creek along the northeast side of the Penn Central Railroad Co. tracks.

Geologic Unit: Martinsburg Formation, Ordovician

Description: Olive gray (5 Y 4/1) to dark greenish-gray (5 GY 4/1), moderately weathered, fissile shale is exposed in the lower portion of the railroad cut. Weathering of the shale becomes progressively more severe in the upper portions of the exposure. Fragments of shale on the slope are relatively small, averaging 1 to 2 inches, and tend to be platy to pencil-shaped. The exposure is about 50 feet long and 10 to 15 feet high.

Attitude of Bedding: Indistinct. Cleavage: N20E, 60-70S.

Sampled Interval: Channel sample of 15 stratigraphic feet from the lower (less weathered) portion of the exposure.

Type of Material: Shale

Ceramic Testing Laboratory: Tuscaloosa

Chemical Analysis:

Analyst: Conwell	%
L.O.I. @ 1,000°C	4.86
H_2O Loss @ 110°C	0.98
Combined H_2O	4.34

Mineralogy (X-ray):

	%	Accuracy (±%)
Quartz	30	8
Mica	56	10
Kaolinite	0	—

Chemical Analysis:

Analyst: Conwell	%
SiO_2	61.30
Al_2O_3	17.48
Fe_2O_3	4.61
FeO	2.63
CaO	1.21
MgO	3.05
CO_2	0.20
Na_2O	1.00
K_2O	2.54
TiO_2	0.91
P_2O_5	NA
MnO	NA
S (total)	0.04
C (total)	0.09

Mineralogy (X-ray):

	%	Accuracy (±%)
C-V-Mo	7	3
Feldspar	2	1

Remarks:

Other Properties:

pH: 6.40
P.C.E.: NA
Water of Plasticity (%): 15.9
Drying Shrinkage (%): 2.5
Dry Strength: Low
Drying Characteristics: Satisfactory
Workability: Mealy; low plasticity

Slow-Firing Tests:

Temp. °F	*Color*	*Hardness*	*% Shk.*	*% Absorb.*	*% App. Por.*	*Approx. Sp. Gr.*
1800	Tan	Moh's 2	2.5	19.7	—	1.81
1900	Dark tan	Moh's 2	2.5	12.9	—	1.85
2000	Light brown	Moh's 5	2.5	7.9	—	2.02
2100	Brown	Moh's 6	7.5	1.9	—	2.12
2200	Overfired	—	—	—	—	—
2300	Overfired	—	—	—	—	—

Pyrometric cone equivalent: NA **Bloating test:** Negative

Remarks: Short working; narrow firing range.

Bloating Tests (Quick-Firing): NA

Other Tests: None

Potential Uses: No designated ceramic use.

Remarks: This site was sampled to fill a gap between other samples that tested as satisfactory for use as a lightweight aggregate raw material.

FRANKLIN COUNTY St. Thomas Twp.

Sample Number
109-6-7

Quadrangle: Mercersburg 15′; St. Thomas 7½′

Location: The sampled road cut site is approximately 1.3 miles south of St. Thomas, Pa., on the east side of a bend in an undesignated road which parallels Campbell Run.

Geologic Unit: Martinsburg Formation, Ordovician

Description: The road cut exposure is 600 feet long and from 6 to 10 feet high. It has several moderately to highly weathered, limy shale layers approximately 2 inches thick. The shale is moderately to highly weathered and breaks out in ¼ to 1 inch thick, pencil-like

fragments. The fresh shale is brownish gray (5 YR 4/1), and weathers pale yellowish brown (10 YR 6/2).

Attitude of Bedding: N32E, 61S (apparent dip)

Sampled Interval: Composite sample collected every few inches across the outcrop.

Type of Material: Shale

Ceramic Testing Laboratory: Tuscaloosa

Chemical Analysis:

Analyst: Conwell	%
L.O.I. @ 1,000°C	5.14
H_2O Loss @ 110°C	0.93
Combined H_2O	5.72
SiO_2	59.08
Al_2O_3	18.62
Fe_2O_3	5.15
FeO	2.23
CaO	1.61
MgO	2.89
CO_2	0.31
Na_2O	1.00
K_2O	2.88
TiO_2	0.95
P_2O_5	NA
MnO	NA
S (total)	0.06
C (total)	0.28

Mineralogy (X-ray):

	%	Accuracy (±%)
Quartz	26	6
Mica	53	8
Kaolinite	4	2
C-V-Mo	10	3
Feldspar	2	1

Remarks:

Other Properties:

pH: 7.8
P.C.E.: NA
Water of Plasticity (%): 18.8
Drying Shrinkage (%): 2.5
Dry Strength: Low
Drying Characteristics: No drying defects
Workability: Low plasticity

Slow-Firing Tests:

Temp. °F	*Color*	*Hardness*	*% Shk.*	*% Absorb.*	*% App. Por.*	*Approx. Sp. Gr.*
1800	Tan	Moh's 2	2.5	15.5	28.7	1.85
1900	Tan	Moh's 3	2.5	12.1	23.6	1.95
2000	Light brown	Moh's 4	5.0	5.6	12.3	2.19
2100	Dark brown	Moh's 5	5.0	0.0	0.0	2.09
2200	—	—	Expanded	—	—	—
2300						

Pyrometric cone equivalent: NA **Bloating test:** Positive

Bloating Tests (Quick-Firing):

Crushing characteristics: Angular Particle size: ¾″ Lumps
Drying characteristics: NA Retention time: 15 minutes

Temp. °F	*Bulk Density*	*Lb/Ft³*	*% Absorb.*	*Remarks*
1800	—	—	—	
1900	1.38	86.1	4.0	Slight expansion
2000	0.91	56.8	5.9	Good pore structure
2100	1.08	67.4	5.0	Overfired
2200	—	—	—	
2300	—	—	—	

Recommendations: Promising raw material for lightweight aggregate (coated); trial run in rotary kiln should be made.

ROTARY KILN TESTS:

Raw Material:

Screen Analysis (Crushed through a hammermill with 1½" screen)

Size		*Percent Retained*
—¾"	+ ½"	14.2
—½"	+ ⅜"	13.9
—⅜"	+ 4 mesh	29.0
—4 mesh	+ 8 mesh	8.8
—8 mesh	PAN	34.1
	TOTAL	100.0

Crushing loss (—4 mesh) 42.9%

Fragment shape: Angular and platy

Firing Data:

Size range of feed: —¾ + 4 mesh   Pour weight of feed: 70.0 lb/ft³

Bloating temperature: 1990°F

Logging temperature* (*Nodules sticking together): 2050°F

Fired Material (all fired material crushed through a roll crusher)

Screen Analysis* (*ASTM Designation C 311-59T) in percentages by weight passing sieves:

Size designation	¾"	½"	⅜"	No. 4	No. 8	No. 16	No. 50	No. 100
Fine	—	—	100.0	65.0	—	25.0	11.0	8.0
Coarse	100.0	82.0	53.0	12.0	5.7	—	—	—

Loose pour weight* (*ASTM Designation C 311-59T):

Fine: 45.0 lb/ft³   Coarse: 42.5 lb/ft³

Color: Light brown

COMMENTS: Best potential for lightweight aggregate. Angular fragments; fine pores; good crushing. Promising for lightweight aggregate.

Other Tests: Slightly effervescent with HCl.

Potential Uses: Best potential for lightweight aggregate.

FRANKLIN COUNTY Antrim Twp.

Sample Number

109-9-6

Quadrangle: Mercersburg 15'; Williamson 7½'

Location: Shale quarry on north side of road leading southeast from Williamson, Pa., 2.5 miles from Williamson or 1.6 miles south-southwest of Stone Bridge, Pa.

Geologic Unit: Martinsburg Formation, Ordovician

Description: Grayish olive (10 Y 4/2) to light olive (5 Y 5/2), moderately weathered, fissile to thin-bedded shales are exposed in the quarry. Several folds and faults can be seen in the north face of the quarry. The folds plunge 13 to 15 degrees to the southwest; reliable attitudes were not obtained on the faults but dips are approximately 20 to 30 degrees to the southeast. The quarry face averages 10 feet in height and parallels the road for about 75 feet.

Sampled Interval: Composite sample of quarry face.

Type of Material: Shale

Ceramic Testing Laboratory: Tuscaloosa

Chemical Analysis:

Analyst: Conwell	%
L.O.I. @ 1,000°C	4.89
H_2O Loss @ 110°C	1.26
Combined H_2O	4.99
SiO_2	62.06
Al_2O_3	16.27
Fe_2O_3	3.96
FeO	2.45
CaO	1.61
MgO	2.95
CO_2	0.10
Na_2O	1.08
K_2O	2.40
TiO_2	0.95
P_2O_5	NA
MnO	NA
S (total)	0.07
C (total)	0.49

Mineralogy (X-ray):

	%	Accuracy (±%)
Quartz	38	5
Mica	40	8
Kaolinite	5	3
C-V-Mo	10	3
Feldspar	2	1

Remarks:

Other Properties:

pH: 6.40
P.C.E.: NA
Water of Plasticity (%): 17.2
Drying Shrinkage (%): 2.5
Dry Strength: Low
Drying Characteristics: No drying defects
Workability: Gritty, low plasticity

Slow-Firing Tests:

Temp. °F	*Color*	*Hardness*	*% Shk.*	*% Absorb.*	*% App. Por.*	*Approx. Sp. Gr.*
1800	Tan	Moh's 2	2.5	13.8	—	1.86
1900	Dark tan	Moh's 2	2.5	11.8	—	1.93
2000	Light brown	Moh's 6	5.0	8.1	—	2.04
2100	Brown	Moh's 7	7.5	2.0	—	2.12
2200	Overfired	—	—	—	—	—
2300	Overfired	—	—	—	—	—

Pyrometric cone equivalent: NA **Bloating test:** Positive

Remarks: Short working; narrow firing range.

Bloating Tests (Quick-Firing):

Crushing characteristics: Angular — Particle size: —¾″ + ½″
Drying characteristics: NA — Retention time: 15 minutes

Temp. °F	Bulk Density	Lb/Ft^3	% Absorb.	Remarks
1800				
1900				
2000	1.8	112	4.6	Light brown
2100	0.66	41	3.1	Excellent pore structure
2200	0.75	47	7.7	Rounded nodules
2300				

Recommendations: Trial run in rotary kiln should be made.

ROTARY KILN TESTS:

Raw Material:

Screen Analysis (Crushed through a hammermill with 1½" screen)

Size		Percent Retained
—¾"	+ ½"	19.5
—½"	+ ⅜"	16.8
—⅜"	+ 4 mesh	34.0
—4 mesh	+ 8 mesh	12.7
—8 mesh	PAN	17.0
	TOTAL	100.0

Crushing loss (—4 mesh) 29.4%

Fragment shape: Acicular and angular

Firing Data:

Size range of feed: —¾ + 4 mesh Pour weight of feed: 86.9 lb/ft^3

Bloating temperature: 2085°F

Logging temperature* (*Nodules sticking together): 2120°F

Fired Material (all fired material crushed through a roll crusher)

Screen Analysis* (*ASTM Designation C 311-59T) in percentages by weight passing sieves:

Size designation	¾"	½"	⅜"	No. 4	No. 8	No. 16	No. 50	No. 100
Fine	—	—	100.0	30.0	—	12.0	8.6	7.8
Coarse	100.0	63.0	22.0	8.0	7.7	—	—	—

Loose pour weight* (*ASTM Designation C 311-59T):

Fine: 41.5 lb/ft^3 Coarse: 36.8 lb/ft^3

Color: Dark brown

COMMENTS: Best potential for lightweight aggregate product; Rounded acicular and angular lumps; good pore structure; satisfactory crushing characteristics.

Other Tests: None

Potential Uses: Best potential for lightweight aggregate.

Remarks: The quarry is intermittently operated for fill material.

FRANKLIN COUNTY Antrim Twp.

Sample Number

109-9-8

Quadrangle: Mercersburg 15′; Williamson 7½′

Location: Quarry approximately ⅛ mile north of Pa. Route 16 and 1.5 miles east of Upton, Pa.

Geologic Unit: Martinsburg Formation, Ordovician

Description: The shale is limy and highly weathered. The quarry is approximately 300 feet long and 15 feet high.

Sampled Interval: Composite sample of quarry.

Type of Material: Shale

Ceramic Testing Laboratory: Tuscaloosa

Chemical Analysis:

Analyst: Conwell	%
L.O.I. @ 1,000°C	5.98
H_2O Loss @ 110°C	0.95
Combined H_2O	5.75
SiO_2	61.04
Al_2O_3	17.77
Fe_2O_3	4.28
FeO	1.87
CaO	1.11
MgO	2.55
CO_2	0.20
Na_2O	0.68
K_2O	3.16
TiO_2	0.91
P_2O_5	NA
MnO	NA
S (total)	0.10
C (total)	0.44

Mineralogy (X-ray):

	%	*Accuracy* (±%)
Quartz	23	5
Mica	64	6
Kaolinite	0	—
C-V-Mo	6	3
Feldspar	2	1

Remarks: Mineralogy indicates chemical analysis may be slightly high in SiO_2.

Other Properties:

pH: 5.20
P.C.E.: NA
Water of Plasticity (%): 20.4
Drying Shrinkage (%): 2.5
Dry Strength: Low
Drying Characteristics: No defects
Workability: Low plasticity

Slow-Firing Tests:

Temp. °F	*Color*	*Hardness*	*% Shk.*	*% Absorb.*	*% App. Por.*	*Approx. Sp. Gr.*
1800	Tan	Moh's 2	2.5	16.7	—	1.81
1900	Tan	Moh's 3	5.0	12.5	—	1.96
2000	Light brown	Moh's 4	7.5	5.2	—	2.20
2100	Brown	Moh's 5	7.5	1.0	—	1.99
2200	—	—	Expanded	—	—	—
2300						

Pyrometric cone equivalent: NA **Bloating test:** Negative

Bloating Tests (Quick-Firing): NA

Other Tests: Not effervescent with HCl.

Potential Uses: Should fire to "MW" face brick specifications at about 1950°F.

Remarks: The quarried material is being used for fill. Field relationships suggest that material from this quarry had low potential for ceramic use.

FRANKLIN COUNTY Letterkenny Twp.

Sample Number

118-8-1

Quadrangle: Shippensburg 15'

Location: Road cut on the southwest side of Pa. Route 997, about one mile south of Pleasant Hall, Pa.

Geologic Unit: Martinsburg Formation, Ordovician

Description: Interbedded olive gray, dark-greenish-gray, and medium-dark gray shales and siltstones are exposed in the road cut. The predominant shale beds are fissile; the siltstone beds are as much as 3 inches thick. The rock in the northern portion of the road cut is slightly to moderately weathered; the southern half of the road cut, however, is more intensely weathered. The exposure is about 20 feet high and 500 feet long.

Attitude of Bedding: N25E, 78N; the bedding-cleavage relationship indicates that the beds are right side up.

Sampled Interval: Composite sample of 50 stratigraphic feet.

Type of Material: Shale and siltstone

Ceramic Testing Laboratory: Tuscaloosa

Chemical Analysis:

Analyst: Spectrochemical	%
L.O.I. @ 1,000°C	5.05
H_2O Loss @ 110°C	0.26
Combined H_2O	NA
SiO_2	69.60
Al_2O_3	10.00
Fe_2O_3	4.94
FeO	2.49
CaO	0.70
MgO	1.66
CO_2	0.99
Na_2O	1.80
K_2O	2.80
TiO_2	0.86
P_2O_5	NA
MnO	NA
S (total)	0.05
C (total)	0.35

Mineralogy (X-ray):

	%	Accuracy (±%)
Quartz	37	5
Mica	29	6
Kaolinite	7	5
C-V-Mo	9	3
Feldspar	11	2

Remarks: Mineralogy indicates chemical analysis is low in Al_2O_3.

Other Properties:

pH: 7.80
P.C.E.: NA
Water of Plasticity (%): 25.4
Drying Shrinkage (%): 0.0
Dry Strength: Good
Drying Characteristics: Good; slightly wavy
Workability: Short working; smooth, mealy

Slow-Firing Tests:

Temp. °F	Color	Hardness	% Shk.	% Absorb.	% App. Por.	Approx. Sp. Gr.
1800	Tan	Fair hard	0.1	9.4	—	2.36
1900	Light brown	Hard	5.0	7.7	—	2.35
2000	Chocolate	Very hard	10.0	30.1	—	2.35
2100	Dark brown	Steel hard	10.0	44.6	—	2.29
2200	Dark brown	Very hard	5.5	35.2	—	1.91
2300	Melted	—	—	—	—	—

Pyrometric cone equivalent: NA **Bloating test:** Positive

Remarks: Wavy surface; fair color; high absorption; local expansion.

Bloating Tests (Quick-Firing):

Crushing characteristics: Good Particle size: —¾" + ½"

Drying characteristics: Good Retention time: 15 minutes

Temp. °F	Bulk Density	Lb/Ft³	% Absorb.	Remarks
1800	—			
1900	—			
2000	1.31	82	11.7	Layered expansion
2100	0.74	46	9.7	Layered expansion
2200	0.76	47	4.3	Large and small vesicules
2300				

Recommendations: Good lightweight aggregate; might iron stain.

ROTARY KILN TESTS:

Raw Material:

Screen Analysis (Crushed through a hammermill with 1½" screen)

Size		Percent Retained
—¾"	+ ½"	12.3
—½"	+ ⅜"	13.7
—⅜"	+ 4 mesh	32.6
—4 mesh	+ 8 mesh	9.4
—8 mesh	PAN	32.0
	TOTAL	100.0

Crushing loss (—4 mesh) 41.4%

Fragment shape: Platy

Firing Data:

Size range of feed: —¾ + 4 mesh Pour weight of feed: 72.0 lb/ft³

Bloating temperature: 1970°F

Logging temperature* (*Nodules sticking together): 2020°F

Fired Material (all fired material crushed through a roll crusher)

Screen Analysis* (*ASTM Designation C 311-59T) in percentages by weight passing sieves:

Size designation	¾"	½"	⅜"	No. 4	No. 8	No. 16	No. 50	No. 100
Fine	—	—	100.0	58.5	—	21.5	11.5	8.7
Coarse	100.0	90.0	52.0	20.0	13.0	—	—	—

Loose pour weight* (*ASTM Designation C 311-59T):

Fine: 45.0 lb/ft^3 Coarse: 37.5 lb/ft^3

Color: Dark brown

COMMENTS: Marginal for lightweight aggregate; Undesirable fragment shape of fired product; mostly thin plates; fair crushing; some large pores.

Other Tests: Soluble Br. K. 2.00, Slightly effervescent (carbonates)

Potential Uses: Rotary kiln tests indicate raw material is only marginal for lightweight aggregate. Good quality lightweight aggregate might be produced from this material providing processing techniques can upgrade some of the more desirable properties of the finished product.

FRANKLIN COUNTY Hamilton Twp.

Sample Number

119-1-1

Quadrangle: Chambersburg 15′; Chambersburg 7½′

Location: Quarry on north side of U. S. Route 30, about 3.3 miles west of cemetery at western boundary of Chambersburg and 0.1 mile east of Black Creek.

Geologic Unit: Martinsburg Formation, Ordovician

Description: Medium dark gray to dark gray, thin-bedded, silty shales are exposed in beds 1 to 2 inches thick. Rock fragments are commonly tabular. White quartz fills knife-edge fractures in places, while iron-staining is common where quartz is absent. The rock is only slightly weathered. The height of the exposure is about 13 feet.

Attitude of Bedding: N10E, 37S

Sampled Interval: Channel sample of 10 stratigraphic feet.

Type of Material: Silty shale

Ceramic Testing Laboratory: Tuscaloosa

Chemical Analysis:

Analyst: Spectrochemical	%
L.O.I. @ 1,000°C	4.78
H_2O Loss @ 110°C	0.14
Combined H_2O	NA
SiO_2	68.40
Al_2O_3	11.00
Fe_2O_3	3.24
FeO	4.44

MINERALOGY (X-ray):

	%	*Accuracy* (±%)
Quartz	37	5
Mica	30	6
Kaolinite	14	7
C-V-Mo	10	3
Feldspar	3	1

Remarks: Mineralogy indicates chemical analysis is low in Al_2O_3.

Chemical Analysis:

Analyst: Spectrochemical %

CaO	1.42
MgO	1.72
CO_2	1.21
Na_2O	1.26
K_2O	2.80
TiO_2	0.82
P_2O_5	NA
MnO	NA
S (total)	0.55
C (total)	0.33

Other Properties:

pH: 8.30
P.C.E.: NA
Water of Plasticity (%): 25.5
Drying Shrinkage (%): 0.0
Dry Strength: Good
Drying Characteristics: Good; slightly wavy
Workability: Mealy; smooth, short working

Slow-Firing Tests:

Temp. °F	*Color*	*Hardness*	*% Shk.*	*% Absorb.*	*% App. Por.*	*Approx. Sp. Gr.*
1800	Tan	Fair hard	4.0	5.9	—	2.54
1900	Light brown	Hard	4.0	7.9	—	2.53
2000	Chocolate	Very hard	10.0	30.5	—	2.46
2100	Dark brown	Steel hard	10.0	52.1	—	2.33
2200	Dark brown	Very hard	Expanded	47.3	—	1.47
2300	Melted					

Pyrometric cone equivalent: NA **Bloating test:** Positive

Remarks: Wavy, fair color, high absorption.

Bloating Tests (Quick-Firing):

Crushing characteristics: Good Particle size: —¾″ + ½″
Drying characteristics: Good Retention time: 15 minutes

Temp. °F	*Bulk Density*	*Lb/Ft³*	*% Absorb.*	*Remarks*
1800	—	—	—	
1900	—	—	—	
2000	1.04	65	8.8	Layered expansion
2100	0.61	38	6.6	Layered expansion
2200	0.47	29	3.0	Good skin
2300				

Recommendations: Fine lightweight aggregate possibilities.

ROTARY KILN TESTS:

Raw Material:

Screen Analysis (Crushed through a hammermill with 1½″ screen)

Size		*Percent Retained*
—¾″	+ ½″	11.4
—½″	+ ⅜″	7.9
—⅜″	+ 4 mesh	40.4
—4 mesh	+ 8 mesh	20.7
—8 mesh	PAN	19.6
	TOTAL	100.0

Crushing loss (—4 mesh) 40.3%
Fragment shape: Acicular fragments and thin plates.

Firing Data:

Size range of feed: —¾ + 4 mesh   Pour weight of feed: 101.4 lb/ft³

Bloating temperature: 1950°F

Logging temperature* (*Nodules sticking together): 1980°F

Fired Material (all fired material crushed through a roll crusher)

Screen Analysis* (*ASTM Designation C 311-59T) in percentages by weight passing sieves:

Size designation	¾″	½″	⅜″	No. 4	No. 8	No. 16	No. 50	No. 100
Fine	—	—	100.0	50.0	—	3.0	2.9	2.8
Coarse	100.0	41.5	9.5	7.2	7.2	—	—	—

Loose pour weight* (*ASTM Designation C 311-59T):

Fine: 49.6 lb/ft³   Coarse: 48.5 lb/ft³

Color: Brown

COMMENTS: Undesirable fragment shape of fired product (thin plates). Excessive crushing loss of raw material; mostly thin plates; good pore structure; satisfactory crushing characteristics.

Other Tests: Soluble Br. K. 2.00.
Slightly effervescent with HCl (carbonates)

Potential Uses: Rotary kiln tests suggest this is a marginal raw material for lightweight aggregate use. It is suggested that fair quality lightweight aggregate might be made from this material by proper processing.

FRANKLIN COUNTY Hamilton Twp.

Sample Number
119-1-5

Quadrangle: Chambersburg 15′; Chambersburg 7½′

Location: Road cut about 2.3 miles northwest of Chambersburg, Pa., on the northwest side of the macadam road which intersects U. S. Route 30 about 0.1 mile west of the cemetery at the western edge of Chambersburg.

Geologic Unit: Martinsburg Formation, Ordovician

Description: The exposure is moderately weathered, light olive gray (5 Y 6/1) to olive gray (5 Y 4/1), fissile shale interbedded with a few silty shales in beds 2 to 10 inches thick. Rock fragments on the slope are primarily pencil-shaped with some tabular. Folding of the rock toward the northwest results in a repetition of at least part of the stratigraphic sequence sampled in the southeastern part of the outcrop. The exposure extends for approximately 200 feet along the road and averages about 15 feet in height.

Attitude of Bedding: N45E, 43S (attitude measured at southwestern edge of the outcrop).

Sampled Interval: Composite sample of 30 stratigraphic feet at the southeastern edge of the exposure.

Type of Material: Shale

Ceramic Testing Laboratory: Tuscaloosa

Chemical Analysis:

Analyst: Conwell	%
L.O.I. @ 1,000°C	4.54
H_2O Loss @ 110°C	0.74
Combined H_2O	4.71
SiO_2	63.06
Al_2O_3	15.67
Fe_2O_3	2.80
FeO	4.54
CaO	1.21
MgO	2.68
CO_2	0.54
Na_2O	1.32
K_2O	2.21
TiO_2	0.83
P_2O_5	NA
MnO	NA
S (total)	0.11
C (total)	0.70

Mineralogy (X-ray):

	%	Accuracy (±%)
Quartz	35	5
Mica	31	6
Kaolinite	10	7
C-V-Mo	8	3
Feldspar	11	3

Remarks:

Other Properties:

pH: 6.90
P.C.E.: NA
Water of Plasticity (%): 16.1
Drying Shrinkage (%): 2.5
Dry Strength: Low
Drying Characteristics: Satisfactory
Workability: Gritty; low plasticity

Slow-Firing Tests:

Temp. °F	Color	Hardness	% Shk.	% Absorb.	% App. Por.	Approx. Sp. Gr.
1800	Tan	Moh's 2	2.5	14.7	—	1.81
1900	Dark tan	Moh's 2+	2.5	14.1	—	1.81
2000	Light brown	Moh's 4	5.0	9.5	—	1.94
2100	Dark brown	Moh's 7	7.5	1.9	—	2.03
2200	Overfired	—	—	—	—	—
2300	Overfired	—	—	—	—	—

Pyrometric cone equivalent: NA **Bloating test:** Positive

Remarks: Short working; poor color.

Bloating Tests (Quick-Firing):

Crushing characteristics: Laminar Particle size: —¾" + ½"
Drying characteristics: NA Retention time: 15 minutes

Temp. °F	Bulk Density	Lb/Ft^3	% Absorb.	Remarks
1800	—	—	—	
1900	—	—	—	
2000	1.88	117	3.6	Brown
2100	1.17	73	5.6	Good pore structure
2200	0.97	61	7.0	Angular lumps
2300				

Recommendations: Trial run in rotary kiln should be made.

ROTARY KILN TESTS:

Raw Material:

Screen Analysis (Crushed through a hammermill with 1½″ screen)

Size		Percent Retained
—¾″	+ ½″	24.8
—½″	+ ⅜″	13.4
—⅜″	+ 4 mesh	31.2
—4 mesh	+ 8 mesh	14.7
—8 mesh	PAN	15.9
	TOTAL	100.0

Crushing loss (—4 mesh) 30.6%

Fragment shape: Acicular and angular

Firing Data:

Size range of feed: —¾ + 4 mesh   Pour weight of feed: 88.0 lb/ft^3

Bloating temperature: 1980°F

Logging temperature* (*Nodules sticking together): 2000°F

Fired Material (all fired material crushed through a roll crusher)

Screen Analysis* (*ASTM Designation C 311-59T) in percentages by weight passing sieves:

Size designation	¾″	½″	⅜″	No. 4	No. 8	No. 16	No. 50	No. 100
Fine	—	—	100.0	58.0	—	17.1	12.2	11.0
Coarse	100.0	94.3	76.1	18.1	1.5	—	—	—

Loose pour weight* (*ASTM Designation C 311-59T):

Fine: 47.2 lb/ft^3 Coarse: 41.9 lb/ft^3

Color: Brown

COMMENTS: Short firing range; rounded, acicular lumps; good pore structure; fair crushing characteristics.

Other Tests: Slightly effervescent in HCl.

Potential Uses: The short firing range and fair crushing characteristics indicate that this material may yield fair quality lightweight aggregate.

Remarks: Reason for collecting sample: This sampling site is approximately 2.6 miles northeast of Sample 119-1-1 which tested good for manufacture of fine-sized lightweight aggregate. Sample 119-1-5 is moderately weathered and should be compared against the slightly weathered Sample 119-1-1.

FRANKLIN COUNTY Hamilton Twp.

Sample Number

119-1-9

Quadrangle: Chambersburg 15′; Chambersburg 7½′

Location: Road cut 5 miles northwest of the city square in Chambersburg, Pa. The outcrop is reached by traveling west on U. S. Route 30 to a road leading north just beyond the western city limits at the cemetery on the north side of U. S. Route 30; turn north and continue for 3.5 miles; turn at northwest-bearing road leading to Portico School and travel 0.5 mile to outcrop on south side of road.

Geologic Unit: Martinsburg Formation, Ordovician

Description: Sampling site is a road cut 300 feet long and 6 feet high consisting of slightly weathered, interbedded siltstone and shale. The predominant siltstone is present in 2 inch beds; the shale occurs in ⅛ inch thick beds. The unweathered rock is medium-olive gray (5 Y 5/1) but weathers to a yellowish brown (10 YR 5/4).

Attitude of Bedding: Bedding and cleavage are essentially parallel to each other; N30E, vertical dip.

Sampled Interval: Composite sample every 1.5 feet along roadcut.

Type of Material: Shale

Ceramic Testing Laboratory: Tuscaloosa

Chemical Analysis:

Analyst: Conwell	%
L.O.I. @ 1,000°C	5.20
H_2O Loss @ 110°C	0.70
Combined H_2O	6.00
SiO_2	63.62
Al_2O_3	15.96
Fe_2O_3	4.86
FeO	1.73
CaO	0.71
MgO	2.43
CO_2	0.28
Na_2O	1.00
K_2O	2.64
TiO_2	0.82
P_2O_5	NA
MnO	NA
S (total)	0.02
C (total)	0.33

Mineralogy (X-ray):

	%	Accuracy (±%)
Quartz	36	5
Mica	43	6
Kaolinite	4	3
C-V-Mo	10	3
Feldspar	2	1

Remarks:

Other Properties:

pH: 6.50
P.C.E.: NA
Water of Plasticity (%): 16.4
Drying Shrinkage (%): 2.5
Dry Strength: Low
Drying Characteristics: No defects
Workability: Low plasticity

Slow-Firing Tests:

Temp. °F	*Color*	*Hardness*	*% Shk.*	*% Absorb.*	*% App. Por.*	*Approx. Sp. Gr.*
1800	Tan	Moh's 2	2.5	17.1	31.0	1.81
1900	Light brown	Moh's 3	2.5	13.8	26.2	1.90
2000	Brown	Moh's 4	7.5	8.4	17.6	2.09
2100	Dark brown	Moh's 5	10.0	2.6	5.6	2.15
2200	—	—	Expanded	—	—	—
2300						

Pyrometric cone equivalent: NA **Bloating test:** Negative

Bloating Tests (Quick-Firing): NA

Other Tests: Slightly effervescent with HCl.

Potential Uses: Face brick with "MW" specifications at about 2000°F; however color of brick is not esthetically pleasing.

Remarks: Low green strength; may be limy.

FRANKLIN COUNTY Hamilton Twp.

Sample Number
119-4-4

Quadrangle: Chambersburg 15′; Greencastle 7½′

Location: Quarry about 1.1 miles east of the church in Cashtown, Pa., on the west side of the light-duty macadam road where it turns northeast, parallel to Conococheague Creek.

Geologic Unit: Martinsburg Formation, Ordovician

Description: Light olive gray (5 Y 6/1), olive gray (5 Y 4/1), and medium gray (N 5), moderately weathered, thin-bedded shale is exposed for about 150 feet along the road. Fragments of shale on the slope and on the quarry floor are platy and average about 1.5 inches in length. The working face of the quarry is about 20 feet high.

Attitude of Bedding: Not measured

Sampled Interval: Composite sample representing a 25 foot section of the western part of the quarry.

Type of Material: Shale

Ceramic Testing Laboratory: Norris

Chemical Analysis:

Analyst: Spectrochemical	%
L.O.I. @ 1,000°C	5.24
H_2O Loss @ 110°C	0.51
Combined H_2O	NA
SiO_2	69.00
Al_2O_3	11.60
Fe_2O_3	6.36
FeO	1.07
CaO	0.32
MgO	1.58
CO_2	0.37
Na_2O	0.95
K_2O	3.00
TiO_2	0.80
P_2O_5	NA
MnO	NA
S (total)	> 0.04
C (total)	0.35

Mineralogy (X-ray):

	%	Accuracy (±%)
Quartz	37	5
Mica	43	6
Kaolinite	0	—
C-V-Mo	10	3
Feldspar	2	1

Remarks: Mineralogy indicates chemical analysis is low in Al_2O_3.

Other Properties:

pH: 7.30
P.C.E.: NA
Water of Plasticity (%): 28.0
Drying Shrinkage (%): 4.5
Dry Strength: Good
Drying Characteristics: Good
Workability: Plastic, smooth, short-working

Slow-Firing Tests:

Temp. °F	*Color*	*Hardness*	*% Shk.*	*% Absorb.*	*% App. Por.*	*Approx. Sp. Gr.*
1800	Tan	Fair hard	5.0	6.2	—	2.49
1900	Red tan	Hard	9.0	9.5	—	2.46
2000	Chocolate	Very hard	10.0	35.4	—	2.41
2100	Brown	Steel hard	15.0	78.4	—	2.39
2200	Dark brown	Steel hard	10.0	72.6	—	2.05
2300	Melted	—	—	—	—	—

Pyrometric cone equivalent: NA **Bloating test:** Positive

Remarks: Fire cracks, wavy surface, fair color, very high absorption.

Bloating Tests (Quick-Firing):

Crushing characteristics: Good Particle size: —¾" + ½"
Drying characteristics: Good Retention time: 15 minutes

Temp. °F	*Bulk Density*	*Lb/Ft^3*	*% Absorb.*	*Remarks*
1800	—			
1900	—			
2000	1.19	74	19.7	Slight layered expansion
2100	0.63	39	19.7	Irregular expansion, sticky
2200	0.60	37	9.4	Irregular expansion, sticky
2300				

Recommendations: Fine lightweight aggregate possibility.

ROTARY KILN TESTS:

Raw Material:

Screen Analysis (Crushed through a hammermill with 1½" screen)

Size		*Percent Retained*
—¾"	+ ½"	14.5
—½"	+ ⅜"	12.6
—⅜"	+ 4 mesh	30.3
—4 mesh	+ 8 mesh	9.1
—8 mesh	PAN	33.5
	TOTAL	100.0

Crushing loss (—4 mesh) 42.6%

Fragment shape: Angular

Firing Data:

Size range of feed: —¾ + 4 mesh Pour weight of feed: 90.0 lb/ft^3

Bloating temperature: 2020°F

Logging temperature* (*Nodules sticking together): 2070°F

Fired Material (all fired material crushed through a roll crusher)

Screen Analysis* (*ASTM Designation C 311-59T) in percentages by weight passing sieves:

Size designation	¾"	½"	⅜"	No. 4	No. 8	No. 16	No. 50	No. 100
Fine	—	—	100.0	90.0	—	50.3	15.6	5.5
Coarse	100.0	95.0	58.3	28.3	13.5	—	—	—

Loose pour weight* (*ASTM Designation C 311-59T):

Fine: 46.0 lb/ft^3 Coarse: 44.0 lb/ft^3

Color: Dark brown

COMMENTS: Not promising for lightweight aggregate; undesirable fragment shape of firing product; angular and tabular fragments; poor crushing; fair pore structure.

Other Tests: Soluble Br. K. 1.70

Potential Uses: Rotary kiln tests suggest that the raw material is not promising for lightweight aggregate use.

FRANKLIN COUNTY Antrim Twp.

Sample Number
119-4-7

Quadrangle: Chambersburg 15′; Greencastle 7½′

Location: Quarry about 3.5 miles north-northwest of Greencastle, Pa., on the northwest side of the road between Kauffman, Pa., and Williamson, Pa.

Geologic Unit: Martinsburg Formation, Ordovician

Description: Pale to dark-grayish orange (10 YR 8/6 to YR 6/6), yellowish gray (5 Y 7/2), very dusky red (10 R 2/2), and grayish red (10 R 4/2), thin-bedded shales are exposed in the quarry for a distance of about 150 feet. The shale is moderately to severely weathered. Shale fragments range in size from less than one inch to more than a foot and are commonly olive gray (5 Y 4/1) in the central, less weathered, portion. The height of the quarry wall is 25 feet with an overburden of soil up to 2 feet thick.

Attitude of Bedding: Indistinct. Cleavage: N5W, 68S

Sampled Interval: Random grab sample collected from throughout the quarry.

Type of Material: Shale

Ceramic Testing Laboratory: Tuscaloosa

Chemical Analysis:

Analyst: Conwell	%
L.O.I. @ 1,000°C	4.85
H_2O Loss @ 110°C	0.74
Combined H_2O	5.71
SiO_2	61.48
Al_2O_3	15.77
Fe_2O_3	4.22
FeO	3.74
CaO	0.50
MgO	3.02
CO_2	0.14
Na_2O	1.43
K_2O	2.64
TiO_2	0.86
P_2O_5	NA
MnO	NA
S (total)	0.07
C (total)	0.47

Mineralogy (X-ray):

	%	*Accuracy (±%)*
Quartz	35	6
Mica	40	8
Kaolinite	8	6
C-V-Mo	10	3
Feldspar	2	1

Remarks:

Other Properties:

pH: 6.40
P.C.E.: NA
Water of Plasticity (%): 15.4
Drying Shrinkage (%): 0.0
Dry Strength: Low
Drying Characteristics: Satisfactory
Workability: Gritty; low plasticity

Slow-Firing Tests:

Temp. °F	*Color*	*Hardness*	*% Shk.*	*% Absorb.*	*% App. Por.*	*Approx. Sp. Gr.*
1800	Tan	Moh's 2	0.0	14.1	—	1.80
1900	Dark tan	Moh's 2+	0.0	13.3	—	1.85
2000	Light brown	Moh's 4+	2.5	9.3	—	1.97
2100	Brown	Moh's 6	5.0	3.3	—	2.05
2200	Overfired	—	—	—	—	—
2300	Overfired	—	—	—	—	—

Pyrometric cone equivalent: NA **Bloating test:** Positive

Remarks: Short working; color marginal

Bloating Tests (Quick-Firing):
Crushing characteristics: Angular — Particle size: —¾″ + ½″
Drying characteristics: NA — Retention time: 15 minutes

Temp. °F	*Bulk Density*	*Lb/Ft³*	*% Absorb.*	*Remarks*
1800				
1900				
2000	1.97	123	4.8	Rich brown
2100	1.09	68	7.0	Good pore structure
2200	0.64	40	9.3	Laminae
2300				

Recommendations: Trial run in rotary kiln should be made.

ROTARY KILN TESTS

Raw Material:

Screen Analysis (Crushed through a hammermill with 1½″ screen)

Size		*Percent Retained*
—¾″	+ ½″	14.1
—½″	+ ⅜″	13.7
—⅜″	+ 4 mesh	30.0
—4 mesh	+ 8 mesh	15.0
—8 mesh	PAN	27.2
	TOTAL	100.0

Crushing loss (—4 mesh) 42.2%
Fragment shape: Thin plates and angular fragments.

Firing Data:

Size range of feed: —¾ + 4 mesh — Pour weight of feed: 99.0 lb/ft³
Bloating temperature: 1960°F
Logging temperature* (*Nodules sticking together): 2020°F

Fired Material (all fired material crushed through a roll crusher)
Screen Analysis* (*ASTM Designation C 311-59T) in percentages by weight passing sieves:

Size designation	¾″	½″	⅜″	No. 4	No. 8	No. 16	No. 50	No. 100
Fine	—	—	100.0	78.7	—	50.6	40.2	34.5
Coarse	100.0	74.0	20.0	2.0	1.8	—	—	—

Loose pour weight* (*ASTM Designation C 311-59T):
Fine: 52.5 lb/ft³ — Coarse: 42.8 lb/ft³
Color: Dark brown

COMMENTS: Excessive crushing loss of raw material. Undesirable fragment shape of fired product (thin plates); thin plates and rounded lumps; good pore structure; poor crushing characteristics.

Other Tests: None

Potential Uses: Firing range and good pore structure may make this material acceptable for producing fair quality lightweight aggregate providing excessive crushing loss of raw material or fired product crushing characteristics and fragment shape do not completely rule out such use.

FRANKLIN COUNTY Guilford Twp.

Sample Number
119-4-8

Quadrangle: Chambersburg 15′; Greencastle 7½′

Location: Quarry northwest of U. S. Route 11, about 0.75 mile northwest of the center of Marion, Pa.

Geologic Unit: Martinsburg Formation, Ordovician

Description: Dark gray (N 3), thin-bedded shales are exposed in a quarry 200 feet by 300 feet and 15 feet high. A few siltstone beds are interbedded with the shale beds; bedding ranges from several inches to more than a foot in thickness. Weathering is slight to moderate. Fragments of the shale are tabular to pencil-like in shape. The cleavage bedding relationship suggests that the beds are right side up.

Attitude of Bedding: N10E, 85N

Sampled Interval: Composite sample of 25 stratigraphic feet.

Type of Material: Shale

Ceramic Testing Laboratory: Tuscaloosa

Chemical Analysis:

Analyst: Conwell	%
L.O.I. @ 1,000°C	9.82
H_2O Loss @ 110°C	0.38
Combined H_2O	3.82
SiO_2	51.48
Al_2O_3	17.51
Fe_2O_3	1.18
FeO	5.62
CaO	6.65
MgO	2.71
CO_2	5.48
Na_2O	0.92
K_2O	2.64
TiO_2	0.75
P_2O_5	NA
MnO	NA
S (total)	0.04
C (total)	0.54

Mineralogy (X-ray):

	%	Accuracy (±%)
Quartz	15	5
Mica	37	8
Kaolinite	8	7
C-V-Mo	4	3
Feldspar	1	1

Remarks: High carbonate content—data are of minimum reliability.

Other Properties:

pH: 7.40
P.C.E.: NA
Water of Plasticity (%): 12.7
Drying Shrinkage (%): 0.0
Dry Strength: Low
Drying Characteristics: Satisfactory
Workability: Gritty; non-plastic

Slow-Firing Tests:

Temp. °F	*Color*	*Hardness*	*% Shk.*	*% Absorb.*	*% App. Por.*	*Approx. Sp. Gr.*
1800	Sand	Moh's 2	0.0	18.7	—	1.78
1900	Sand	Moh's 2	0.0	18.7	—	1.80
2000	Sand	Moh's 3	0.0	16.8	—	1.83
2100	Dark brown	Moh's 5	0.0	7.8	—	1.89
2200	Melted	—	—	—	—	—
2300						

Pyrometric cone equivalent: NA **Bloating test:** Positive

Remarks: Very short working; poor color.

Bloating Tests (Quick-Firing):

Crushing characteristics: Laminar Particle size: —¾″ + ½″

Drying characteristics: NA Retention time: 15 minutes

Temp. °F	*Bulk Density*	*Lb/Ft³*	*% Absorb.*	*Remarks*
1800				
1900				
2000	1.26	78	20.3	Gray brown
2100	1.04	65	9.4	Good pore structure
2200	1.12	70	5.5	Angular lumps
2300				

Recommendations: Trial run in rotary kiln should be made.

ROTARY KILN TESTS

Raw Material:

Screen Analysis (Crushed through a hammermill with 1½″ screen)

Size		*Percent Retained*
—¾″	+ ½″	20.3
—½″	+ ⅜″	17.2
—⅜″	+ 4 mesh	38.2
—4 mesh	+ 8 mesh	11.7
—8 mesh	PAN	12.6
	TOTAL	100.0

Crushing loss (—4 mesh) 24.3%

Fragment shape: Thin plates and angular fragments

Firing Data:

Size range of feed: —¾ + 4 mesh Pour weight of feed: 97.0 lb/ft³

Bloating temperature: 2030°F

Logging temperature* (*Nodules sticking together): 2040°F

Fired Material (all fired material crushed through a roll crusher)

Screen Analysis* (*ASTM Designation C 311-59T) in percentages by weight passing sieves:

Size designation	¾″	½″	⅜″	No. 4	No. 8	No. 16	No. 50	No. 100
Fine	—	—	100.0	44.0	—	11.5	7.9	7.5
Coarse	100.0	57.0	29.0	11.0	9.0	—	—	—

Loose pour weight* (*ASTM Designation C 311-59T):

Fine: 40.6 lb/ft³ Coarse: 30.4 lb/ft³

Color: Brown

COMMENTS: Short firing range; undesirable fragment shape of fired product (thin plates); thin plates and angular lumps; fair pore structure; satisfactory crushing characteristics.

Other Tests: None

Potential Uses: May make a fair quality lightweight aggregate.

FRANKLIN COUNTY Antrim Twp.

Sample Number
119-7-2

Quadrangle: Chambersburg 15′; Greencastle 7½′

Location: Quarry on the north side of Pa. Route 16 about 1.2 miles west of Greencastle, Pa.

Geologic Unit: Martinsburg Formation, Ordovician

Description: Medium-dark gray to dark gray, interbedded shales and siltstones are exposed in a quarry about 700 feet long east to west. The average thickness of the beds is 1.5 inches. Iron-staining occurs along fractures. The quarry face is about 20 feet high; the lower five feet are very slightly weathered and the upper 15 feet consist of highly weathered soil and rock fragments.

Attitude of Bedding: N20E, 80S

Sampled Interval: Composite sample collected from the western 500 feet of the quarry.

Type of Material: Shale and siltstone

Ceramic Testing Laboratory: Norris

Chemical Analysis:

Analyst: Spectrochemical	%
L.O.I. @ 1,000°C	5.44
H_2O Loss @ 110°C	0.16
Combined H_2O	NA
SiO_2	66.00
Al_2O_3	12.00
Fe_2O_3	3.99
FeO	3.47
CaO	1.99
MgO	1.39
CO_2	1.36
Na_2O	1.65
K_2O	3.20
TiO_2	0.85
P_2O_5	NA
MnO	NA
S (total)	0.75
C (total)	0.54

Mineralogy (X-ray):

	%	Accuracy (±%)
Quartz	37	5
Mica	33	6
Kaolinite	20	7
C-V-Mo	0	
Feldspar	4	2

Remarks: Mineralogy indicates chemical analysis is low in Al_2O_3.

Other Properties:

pH: 8.30
P.C.E.: NA
Water of Plasticity (%): 23.8
Drying Shrinkage (%): 0.0
Dry Strength: Good
Drying Characteristics: Good, some scum
Workability: Plastic, smooth, long-working

Slow-Firing Tests:

Temp. °F	*Color*	*Hardness*	*% Shk.*	*% Absorb.*	*% App. Por.*	*Approx. Sp. Gr.*
1800	Light brown	Fair hard	5.0	5.8	—	2.55
1900	Reddish brown	Hard	5.0	7.7	—	2.48
2000	Brown	Very hard	7.5	12.8	—	2.44
2100	Chocolate	Steel hard	10.0	29.7	—	2.40
2200	Dark brown	Hard	5.0	41.6	—	1.64
2300	Melted	—	—	—	—	—

Pyrometric cone equivalent: NA **Bloating test:** Positive

Remarks: Scumming, slightly wavy, high absorption, uneven bloating, poor color.

Bloating Tests (Quick-Firing):

Crushing characteristics: Fine Particle size: —¾″ + ½″
Drying characteristics: Good Retention time: 15 minutes

Temp. °F	*Bulk Density*	*Lb/Ft³*	*% Absorb.*	*Remarks*
1800	—	—	—	
1900	—	—	—	
2000	1.20	75	14.2	Layered expansion
2100	0.81	50	7.6	Layered expansion, good skin
2200	0.64	40	5.2	Layered expansion, good skin
2300				

Recommendations: Fine lightweight aggregate if carbonate content not too high.

ROTARY KILN TESTS

Raw Material:

Screen Analysis (Crushed through a hammermill with 1½″ screen)

Size	*Percent Retained*
—¾″ + ½″	27.7
—½″ + ⅜″	22.1
—⅜″ + 4 mesh	28.2
—4 mesh + 8 mesh	9.3
—8 mesh PAN	12.7
TOTAL	100.0

Crushing loss (—4 mesh) 22.0%

Fragment shape: Thin plates and angular fragments

Firing Data:

Size range of feed: —¾ + 4 mesh Pour weight of feed: 91.5 lb/ft³

Bloating temperature: 1975°F

Logging temperature* (*Nodules sticking together): 2030°F

Fired Material (all fired material crushed through a roll crusher)

Screen Analysis* (*ASTM Designation C 311-59T) in percentages by weight passing sieves:

Size designation	¾″	½″	⅜″	No. 4	No. 8	No. 16	No. 50	No. 100
Fine	—	—	100.0	43.0	—	5.0	1.0	0.5
Coarse	100.0	84.0	59.0	23.0	6.0	—	—	—

Loose pour weight* (*ASTM Designation C 311-59T):

Fine: 46.1 lb/ft³ Coarse: 42.8 lb/ft³

Color: Brown

COMMENTS: Undesirable fragment shape of fired product (thin plates); mostly thin plates. Good pore structure. Satisfactory crushing characteristics.

Other Tests: Soluble Br. K. 3.00 (causes scum).

Potential Uses: Rotary kiln lightweight aggregate of good quality could be produced from this material for uses in which thin-plate fragments are not a deterrent to utilization.

FRANKLIN COUNTY Antrim Twp.

Sample Number
119-7-3

Quadrangle: Chambersburg 15′; Greencastle 7½′

Location: Quarry in the southwestern part of Greencastle, Pa., about 0.4 mile from the city square.

Geologic Unit: Martinsburg Formation, Ordovician

Description: Olive gray (5 Y 4/1) to medium-dark gray (N 4), thin-bedded shales are exposed in a quarry 500 by 200 feet in plan and up to 50 feet deep. Some siltstone beds are interbedded with the shales. Iron-oxide staining and secondary silica occur along fractures. Rock fragments are platy and irregular in shape. The lower 20 feet of the highwall are only slightly weathered, but the upper 30 feet are moderately to intensely weathered. Limestone is faulted against the shale at the eastern edge of the quarry.

Attitude of Bedding: N30-40E, 79S

Sampled Interval: Composite sample of the rock in the eastern 125 feet of the quarry.

Type of Material: Shale

Ceramic Testing Laboratory: Norris

Chemical Analysis:

Analyst: Spectrochemical %

L.O.I. @ 1,000°C	5.22
H_2O Loss @ 110°C	0.12
Combined H_2O	NA
SiO_2	64.10
Al_2O_3	14.00
Fe_2O_3	3.34
FeO	4.09
CaO	1.95
MgO	1.46
CO_2	1.54
Na_2O	1.58
K_2O	3.30
TiO_2	0.83
P_2O_5	NA
MnO	NA
S (total)	0.97
C (total)	0.43

Mineralogy (X-ray):

	%	Accuracy (±%)
Quartz	28	5
Mica	44	6
Kaolinite	13	7
C-V-Mo	7	3
Feldspar	2	1

Remarks: Mineralogy indicates chemical analysis is low in Al_2O_3.

Other Properties:

pH: 8.40
P.C.E.: NA
Water of Plasticity (%): 14.4
Drying Shrinkage (%): 2.0
Dry Strength: Poor
Drying Characteristics: Fair; rough surface; scum
Workability: Mealy; Short-working

Slow-Firing Tests:

Temp. °F	*Color*	*Hardness*	*% Shk.*	*% Absorb.*	*% App. Por.*	*Approx. Sp. Gr.*
1800	Light brown	Fair hard	3.0	7.1	—	2.53
1900	Light brown	Fair hard	3.0	7.8	—	2.48
2000	Brown	Fair hard	3.0	9.0	—	2.37
2100	Brown	Hard	3.0	17.2	—	2.29
2200	Dark brown	Hard	1.0	13.4	—	1.93
2300						

Pyrometric cone equivalent: NA **Bloating test:** Positive

Remarks: Scumming; rough surface; too soft; high absorption.

Bloating Tests (Quick-Firing):

Crushing characteristics: Fair-shaly — Particle size: —¾″ + ½″
Drying characteristics: Good — Retention time: 15 minutes

Temp. °F	*Bulk Density*	*Lb/Ft³*	*% Absorb.*	*Remarks*
1800	—			
1900	—			
2000	1.57	98	9.5	Good skin
2100	0.65	40	6.8	Fine skin
2200	0.42	26	3.1	Fine skin, uneven vesecules
2300				

Recommendations: Fine lightweight aggregate possibilities, if carbonate content is not too high.

ROTARY KILN TESTS:

Raw Material:

Screen Analysis (Crushed through a hammermill with 1½″ screen)

Size		*Percent Retained*
—¾″	+ ½″	32.0
—½″	+ ⅜″	15.0
—⅜″	+ 4 mesh	27.7
—4 mesh	+ 8 mesh	10.7
—8 mesh	PAN	14.6
	TOTAL	100.0

Crushing loss (—4 mesh) 25.3%

Fragment shape: Thin plates

Firing Data:

Size range of feed: ¾ + 4 mesh — Pour weight of feed: 88.2 lb/ft³
Bloating temperature: 1980°F
Logging temperature* (*Nodules sticking together): 2000°F

Fired Material (all fired material crushed through a roll crusher)
Screen Analysis* (*ASTM Designation C 311-59T) in percentages by weight passing sieves:

Size designation	¾″	½″	⅜″	No. 4	No. 8	No. 16	No. 50	No. 100
Fine	—	—	100.0	49.2	—	8.4	4.1	3.3
Coarse	100.0	87.3	61.0	17.9	8.6	—	—	—

Loose pour weight* (*ASTM Designation C 311-59T):
Fine: 53.6 lb/ft³ — Coarse: 37.9 lb/ft³
Color: Gray-brown

COMMENTS: Short firing range; undesirable fragment shape of fired product (thin plates); mostly thin plates; good pore structure. Satisfactory crushing characteristics.

Other Tests: Highly effervescent in HCl.
Soluble Br. K. 2.80

Potential Uses: Doubtful for use as a rotary kiln lightweight aggregate raw material. Fair quality lightweight aggregate might be produced if the firing range can be improved.

Remarks: 5-6% carbonate.

FRANKLIN COUNTY Antrim Twp.

Sample Number

119-7-6

Quadrangle: Chambersburg 15′; Greencastle 7½′

Location: Road cut located 1.75 miles northwest of Greencastle along the road from Greencastle to Williamson, Pa.

Geologic Unit: Martinsburg Formation, Ordovician

Description: Moderate yellow brown (10 YR 5/4) to dusky yellow brown (10 YR 2/2), thin-bedded shale is exposed for a distance of about 300 feet along the north side of the road. The shale is relatively soft and moderately weathered. Shale fragments are irregular to tabular in shape and average several inches in length. Iron-oxide staining is common along fracture surfaces. A series of folds and some faults can be seen in the exposure.

Attitude of Bedding: No measurements taken; folded.

Sampled Interval: Composite sample of the eastern half of the exposure.

Type of Material: Shale

Ceramic Testing Laboratory: Tuscaloosa

Chemical Analysis:

Analyst: Conwell	%
L.O.I. @ 1,000°C	5.48
H_2O Loss @ 110°C	0.77
Combined H_2O	4.73
SiO_2	58.14
Al_2O_3	19.74
Fe_2O_3	5.54
FeO	2.27
CaO	0.40
MgO	2.34
CO_2	0.45
Na_2O	0.92
K_2O	3.31
TiO_2	0.44
P_2O_5	NA
MnO	NA
S (total)	0.07
C (total)	0.44

Mineralogy (X-ray):

	%	Accuracy (±%)
Quartz	30	5
Mica	46	6
Kaolinite	9	6
C-V-Mo	8	3
Feldspar	2	1

Remarks:

Other Properties:

pH: 6.00
P.C.E.: NA
Water of Plasticity (%): 16.5
Drying Shrinkage (%): 0.0
Dry Strength: Low
Drying Characteristics: Satisfactory
Workability: Gritty; low plasticity

Slow-Firing Tests:

Temp. °F	*Color*	*Hardness*	*% Shk.*	*% Absorb.*	*% App. Por.*	*Approx. Sp. Gr.*
1800	Tan	Moh's 2	0.0	15.3	—	1.85
1900	Dark tan	Moh's 3	0.0	11.2	—	2.07
2000	Light brown	Moh's 4	0.0	6.8	—	2.11
2100	Dark red	Moh's 7	2.5	0.6	—	2.34
2200	Dark brown	Moh's 7+	5.0	0.0	—	1.98
2300	Dark brown	Moh's 8	5.0	0.4	—	2.04

Pyrometric cone equivalent: NA **Bloating test:** Positive

Remarks: Rather short; fires to a good dark red.

Bloating Tests (Quick-Firing):

Crushing characteristics: Laminar — Particle size: —¾" + ½"
Drying characteristics: NA — Retention time: 15 minutes

Temp. °F	*Bulk Density*	*Lb/Ft³*	*% Absorb.*	*Remarks*
1800	—	—	—	
1900	—	—	—	Bulk density too high
2000	1.68	105	8.1	
2100	1.12	70	5.9	
2200	1.65	103	8.4	
2300				

Recommendations: Not promising for lightweight aggregate.

Other Tests: None

Potential Uses: Face Brick; quarry tile

Remarks: Results of preliminary bloating tests do not justify trial runs in rotary kiln.

LANCASTER COUNTY Elizabeth Twp.

Sample Number
168-3-8A

Quadrangle: Lancaster 15′; Lititz 7½′

Location: Quarry south of Hammer Creek, 2.9 miles north of Lititz on the east side of Pa. Route 501.

Geologic Unit: Cocalico Formation, Ordovician

Description: Gray olive, light-olive gray, and yellowish gray, moderately weathered shales are exposed in the quarry. The quarry is 4 to 15 feet high and has a soil overburden. Fragments of weathered shale from this zone are tabular in shape and usually range from 1 to 15 inches in length. Dusty brown to grayish brown stains are common along fractures and cleavage.

Attitude of Bedding: N50E, 15N

Sampled Interval: Channel sample of quarry wall.

Type of Material: Shale

Ceramic Testing Laboratory: Norris

Chemical Analysis:

Analyst: Spectrochemical	%
L.O.I. @ 1,000°C	3.35
H_2O Loss @ 110°C	0.21
Combined H_2O	NA
SiO_2	68.20
Al_2O_3	13.30
Fe_2O_3	6.03
FeO	1.00
CaO	0.17
MgO	1.42

Mineralogy (X-ray):

	%	*Accuracy (±%)*
Quartz	32	7
Mica	30	12
Kaolinite	20	8
C-V-Mo	11	5
Feldspar	4	2

Remarks: Mineralogy indicates chemical analysis low in Al_2O_3.

Chemical Analysis:

Analyst: Spectrochemical %

CO_2	0.26
Na_2O	1.65
K_2O	3.98
TiO_2	0.88
P_2O_5	NA
MnO	NA
S (total)	> 0.02
C (total)	0.11

Other Properties:

pH: 7.75
P.C.E.: NA
Water of Plasticity (%): 31.8
Drying Shrinkage (%): 1.0
Dry Strength: Good
Drying Characteristics: Fair, scum
Workability: Mealy; smooth; short-working

Slow-Firing Tests:

Temp. °F	*Color*	*Hardness*	*% Shk.*	*% Absorb.*	*% App. Por.*	*Approx. Sp. Gr.*
1800	Tan	Soft	1.0	2.9	—	2.06
1900	Tan	Fair hard	1.0	3.3	—	2.08
2000	Light brown	Hard	4.0	4.3	—	2.07
2100	Dark brown	Very hard	10.0	17.0	—	1.99
2200	Black-brown	Steel hard	10.0	209.0	—	1.59
2300	Black	Melted	—	—	—	—

Pyrometric cone equivalent: NA **Bloating test:** Positive

Remarks:

Bloating Tests (Quick-Firing):

Crushing characteristics: Good Particle size: —¾″ + ½″
Drying characteristics: Good Retention time: 15 minutes

Temp. °F	*Bulk Density*	*Lb/Ft³*	*% Absorb.*	*Remarks*
1800	—	—	—	
1900	—	—	—	
2000	2.29	142	14.4	No expansion
2100	2.45	152	8.9	No expansion—layering
2200	1.25	78	16.6	Fair expansion—layered
2300				

Recommendations: Fair lightweight aggregate; a little heavy and poor skin.

ROTARY KILN TESTS:

Raw Material:

Screen Analysis (Crushed through a hammermill with 1½″ screen)

Size		*Percent Retained*
—¾″	+ ½″	31.0
—½″	+ ⅜″	16.5
—⅜″	+ 4 mesh	27.4
—4 mesh	+ 8 mesh	10.1
—8 mesh	PAN	15.0
	TOTAL	100.0

Crushing loss (—4 mesh) 25.1%

Fragment shape: Tabular fragments

Firing Data:
Size range of feed: —¾ + 4 mesh Pour weight of feed: 90.4 lb/ft^3
Bloating temperature: 2030°F
Logging temperature* (*Nodules sticking together): 2070°F

Fired Material (all fired material crushed through a roll crusher)
Screen Analysis* (*ASTM Designation C 311-59T) in percentages by weight passing sieves:

Size designation	¾"	½"	⅜"	No. 4	No. 8	No. 16	No. 50	No. 100
Fine	—	—	100.0	59.0	—	5.9	1.6	1.0
Coarse	100.0	91.3	72.8	34.5	9.4	—	—	—

Loose pour weight* (*ASTM Designation C 311-59T):
Fine: 57.0 lb/ft^3 Coarse: 52.0 lb/ft^3

Color: Dark brown

COMMENTS: Undesirable mixture of bloating and non-bloating materials; angular and flat plates; good pore structure; fair crushing.

Other Tests: Soluble Br. K. 0.90

Potential Uses: Preliminary bloating tests indicate potential use as lightweight aggregate; however, rotary kiln tests indicate material is undersirable for lightweight aggregate use. It may possibly yield a fair quality lightweight aggregate, however, if firing procedures can be controlled. No other designated ceramic use.

LANCASTER COUNTY Elizabeth Twp.

Sample Number
168-3-8B

Quadrangle: Lancaster 15′; Lititz 7½′

Location: Quarry south of Hammer Creek, 2.9 miles north of Lititz on the east side of Pa. Route 501.

Geologic Unit: Cocalico Formation, Ordovician

Description: Dark gray to medium-dark gray shale is exposed in the quarry floor. The quarry measures 150 by 125 feet in plan.

Attitude of Bedding: N60E, 15N

Sampled Interval: Grab sample of shale exposed in quarry floor.

Type of Material: Shale

Ceramic Testing Laboratory: Norris

Chemical Analysis:
Analyst: Spectrochemical %

	%
L.O.I @ 1,000°C	5.56
H_2O Loss @ 110°C	0.09
Combined H_2O	NA
SiO_2	64.30
Al_2O_3	11.10

Mineralogy (X-ray):

	%	*Accuracy (±%)*
Quartz	29	7
Mica	28	12
Kaolinite	22	12
C-V-Mo	11	3
Feldspar	1	1

Chemical Analysis:

Analyst: Spectrochemical %

Fe_2O_3	4.74
FeO	1.62
CaO	5.40
MgO	1.52
CO_2	4.47
Na_2O	1.33
K_2O	3.60
TiO_2	0.77
P_2O_5	NA
MnO	NA
S (total)	0.26
C (total)	0.32

Mineralogy (X-ray):

% Accuracy (±%)

Remarks: Mineralogy indicates chemical analysis is low in Al_2O_3. Carbonates present.

Other Properties:

pH: 9.45
P.C.E.: NA
Water of Plasticity (%): 24.8
Drying Shrinkage (%): 1.0
Dry Strength: Good
Drying Characteristics: Fair; scum; wavy
Workability: Mealy; short-working; smooth

Slow-Firing Tests:

Temp. °F	*Color*	*Hardness*	*% Shk.*	*% Absorb.*	*% App. Por.*	*Approx. Sp. Gr.*
1800	Light tan	Soft	1.0	3.4	—	2.04
1900	Light tan	Soft	1.0	3.4	—	2.01
2000	Tan	Fair hard	1.0	3.6	—	2.00
2100	Dark brown	Hard	4.5	6.4	—	1.91
2200	Black	Melted	Expanded	15.5	—	1.30
2300						

Pyrometric cone equivalent: NA **Bloating test:** Positive

Remarks: Poor color; scum; wavey; too soft.

Bloating Tests (Quick-Firing):

Crushing characteristics: Fair-shaly
Drying characteristics: Good
Particle size: —¾″ + ½″
Retention time: 15 minutes

Temp. °F	*Bulk Density*	*Lb/Ft³*	*% Absorb.*	*Remarks*
1800	—	—	—	
1900	—	—	—	
2000	2.66	166	5.7	No expansion
2100	1.18	74	9.4	Good expansion, good skin
2200	1.21	76	7.7	Good expansion, good skin
2300				

Recommendations: Good lightweight aggregate possibility.

ROTARY KILN TESTS:

Raw Material:

Screen Analysis (Crushed through a hammermill with 1½″ screen)

Size		*Percent Retained*
—¾″	+ ½″	32.4
—½″	+ ⅜″	14.7
—⅜″	+ 4 mesh	25.0
—4 mesh	+ 8 mesh	10.0
—8 mesh	PAN	17.9
	TOTAL	100.0

Crushing loss (—4 mesh) 27.9%

Fragment shape: Angular and tabular fragments

Firing Data:

Size range of feed: —¾ + 4 mesh Pour weight of feed: 101.4 lb/ft³

Bloating temperature: 2080°F

Logging temperature* (*Nodules sticking together): 2150°F

Fired Material (all fired material crushed through a roll crusher)

Screen Analysis* (*ASTM Designation C 311-59T) in percentages by weight passing sieves:

Size designation	¾"	½"	⅜"	No. 4	No. 8	No. 16	No. 50	No. 100
Fine	—	—	100.0	51.0	—	13.0	5.5	3.4
Coarse	100.0	84.8	60.5	25.0	8.2	—	—	—

Loose pour weight* (*ASTM Designation C 311-59T):

Fine: 42.5 lb/ft³ Coarse: 38.5 lb/ft³

COMMENTS: Undesirable mixture of bloating and non-bloating materials; angular and tabular fragments; good pore structure; fair crushing.

Other Tests: Soluble Br. K. 1.20.
Effervescent in HCl.

Potential Uses: Preliminary bloating tests indicate potential use as lightweight aggregate, but rotary kiln tests indicate material is not acceptable for lightweight aggregate; a fair quality lightweight aggregate may possibly be produced from his material, however, if bloating procedures can be controlled. No other designated ceramic use.

LANCASTER COUNTY Rapho Twp.

Sample Number

168-4-10A

Quadrangle: Lancaster 15′; Manheim 7½′

Location: Quarry, operated by C. Robert Fry, along the south side of a macadam road paralleling the south bank of Back Run. The quarry is about 4.5 miles west-southwest of Manheim, Pa.

Geologic Unit: Cocalico Formation, Ordovician

Description: Thin-bedded shales are exposed in the quarry walls which reach a maximum height of 45 feet. The shale in the upper 25 to 30 feet is moderately to highly weathered and ranges from light gray to light olive gray. A composite sample of the shale was collected from 15 to 25 feet below the top of the quarry. Sample 168-4-10A was collected as one of two samples. Sample 168-4-10B represents the second. The quarry dimensions are 400 x 50 x 45 feet.

Attitude of Bedding: N30W, 8N

Sampled Interval: Composite shale sample from 15 to 25 feet below top of quarry.

Type of Material: Shale

Ceramic Testing Laboratory: Tuscaloosa

Chemical Analysis:

Analyst: Conwell	%
L.O.I. @ 1,000°C	5.64
H_2O Loss @ 110°C	0.26
Combined H_2O	3.94
SiO_2	62.94
Al_2O_3	15.51
Fe_2O_3	2.11
FeO	2.59
CaO	3.83
MgO	2.22
CO_2	0.75
Na_2O	1.40
K_2O	2.04
TiO_2	1.11
P_2O_5	NA
MnO	NA
S (total)	None
C (total)	0.74

Mineralogy (X-ray):

	%	*Accuracy (±%)*
Quartz	39	8
Mica	25	8
Kaolinite	17	7
C-V-Mo	11	3
Feldspar	2	1

Remarks:

Other Properties:

pH: 7.30
P.C.E.: NA
Water of Plasticity (%): 17.5
Drying Shrinkage (%): 0.0
Dry Strength: Low
Drying Characteristics: No drying defects
Workability: Low plasticity

Slow-Firing Tests:

Temp. °F	*Color*	*Hardness*	*% Shk.*	*% Absorb.*	*% App. Por.*	*Approx. Sp. Gr.*
1800	Tan	Moh's 2	0.0	18.5	—	1.74
1900	Tan	Moh's 4	0.0	18.0	—	1.76
2000	Light brown	Moh's 6	2.5	13.5	—	1.88
2100	Dark brown	Moh's 6	5.0	3.1	—	2.21
2200	—	—	Expanded	—	—	—
2300						

Pyrometric cone equivalent: NA **Bloating test:** Negative

Remarks: Poor color; short vitrification range.

Bloating Tests (Quick-Firing): NA

Other Tests: Highly effervescent in HCl.

Potential Uses: No designated ceramic use.

LANCASTER COUNTY Rapho Twp.

Sample Number
168-4-10B

Quadrangle: Lancaster 15′; Manheim 7½′

Location: Quarry, operated by C. Robert Fry, along the south side of a macadam road paralleling the south bank of Back Run. The quarry is about 4.5 miles west-southwest of Manheim, Pa.

Geologic Unit: Cocalico Formation, Ordovician

Description: Thin-bedded shales are exposed in the quarry walls which reach a maximum height of 45 feet. Shales in the upper part of the quarry were sampled as Sample 168-4-10A and Sample 168-4-10B. Sample B represents relatively unweathered, medium-dark gray shales which underline Sample A for a stratigraphic interval of 10 feet. The beds range in thickness from less than one inch up to about 4 inches. A few beds are silty and also moderately calcareous. Knife-edge veinlets of calcite commonly visible on joint surfaces. The dimensions of the quarry are 400 x 50 x 45 feet.

Attitude of Bedding: N30W, 8N

Sampled Interval: Composite shale sample from 25 to 35 feet below top of quarry.

Type of Material: Shale

Ceramic Testing Laboratory: Tuscaloosa

Chemical Analysis:

Analyst: Conwell	%
L.O.I. @ 1,000°C	8.59
H_2O Loss @ 110°C	0.14
Combined H_2O	2.91
SiO_2	53.88
Al_2O_3	16.58
Fe_2O_3	1.59
FeO	3.53
CaO	7.26
MgO	2.82
CO_2	6.25
Na_2O	1.21
K_2O	2.40
TiO_2	1.09
P_2O_5	NA
MnO	NA
S (total)	0.61
C (total)	0.30

Mineralogy (X-ray):

	%	Accuracy (±%)
Quartz	20	6
Mica	34	8
Kaolinite	29	7
C-V-Mo	10	3
Feldspar	2	1

Remarks:

Other Properties:

pH: 7.40
P.C.E.: NA
Water of Plasticity (%): 17.2
Drying Shrinkage (%): 2.5
Dry Strength: Low
Drying Characteristics: No drying defects
Workability: Low plasticity

Slow-Firing Tests:

Temp. °F	*Color*	*Hardness*	*% Shk.*	*% Absorb.*	*% App. Por.*	*Approx. Sp. Gr.*
1800	Beige	Moh's 3	2.5	18.5	—	1.74
1900	Beige	Moh's 4	2.5	17.8	—	1.77
2000	Beige	Moh's 5	2.5	16.9	—	1.77
2100	Brown	Moh's 6	2.5	1.4	—	1.85
2200	—	—	Expanded	—	—	—
2300						

Pyrometric cone equivalent: NA **Bloating test:** Negative

Remarks: Poor color; short vitrification range

Bloating Tests (Quick-Firing):

Crushing characteristics: Platy — Particle size: —¾" + ½"
Drying characteristics: NA — Retention time: 15 minutes

Temp. °F	Bulk Density	Lb/Ft^3	% Absorb.	Remarks
1800				
1900	1.76	110	9.4	No bloating
2000	1.13	70	5.9	Selective bloating
2100	1.05	65	11.2	Melting
2200				
2300				

Recommendations: Firing range too short for rotary kiln processing.

Other Tests: Highly effervescent in HCl.

Potential Uses: No designated ceramic use.

LANCASTER COUNTY Rapho Twp.

Sample Number
168-5-9

Quadrangle: Lancaster 15′; Manheim 7½′

Location: Exposure opposite Kauffman Cemetery at the northeast edge of Sporting Hill, Pa., along the northwest side of the macadam road between Sporting Hill and Manheim, Pa.

Geologic Unit: Cocalico Formation, Ordovician

Description: Highly weathered, buff and yellowish-gray, thin-bedded shale is exposed in the road cut. Dusky brown and grayish orange staining is common along the fractures. The beds average less than an inch in thickness and pieces are easily broken off the outcrop. The shale fragments are usually tabular to irregular in shape and seldom exceed six inches in length. The outcrop is 10 feet high and 400 feet long.

Attitude of Bedding: Obscure; Cleavage: N60E, 37S

Sampled Interval: Composite sample of entire outcrop.

Type of Material: Shale

Ceramic Testing Laboratory: Tuscaloosa

Chemical Analysis:

Analyst: Conwell	%
L.O.I. @ 1,000°C	5.99
H_2O Loss @ 110°C	0.44
Combined H_2O	5.26
SiO_2	56.52
Al_2O_3	21.57
Fe_2O_3	5.96
FeO	1.22
CaO	0.20
MgO	2.54
CO_2	0.45
Na_2O	0.27
K_2O	3.36
TiO_2	1.16
P_2O_5	NA
MnO	NA
S (total)	None
C (total)	0.12

Mineralogy (X-ray):

	%	Accuracy (±%)
Quartz	23	8
Mica	45	10
Kaolinite	0	—
C-V-Mo	20	3
Feldspar	2	1

Remarks:

Other Properties:

pH: 6.30
P.C.E.: NA
Water of Plasticity (%): 22.6
Drying Shrinkage (%): 2.5
Dry Strength: Low
Drying Characteristics: No defects
Workability: Low plasticity

Slow-Firing Tests:

Temp. °F	Color	Hardness	% Shk.	% Absorb.	% App. Por.	Approx. Sp. Gr.
1800	Tan	Moh's 2	2.5	24.6	39.6	1.61
1900	Tan	Moh's 2	2.5	20.6	35.6	1.73
2000	Light brown	Moh's 3	5.0	14.6	27.7	1.90
2100	Brown	Moh's 4	12.5	3.8	8.5	2.23
2200	Red brown	Moh's 5	12.5	4.7	10.7	2.27
2300	Dark brown	Moh's 6	12.5	2.9	6.8	2.34

Pyrometric cone equivalent: NA **Bloating test:** Negative

Remarks: Abrupt vitrification. Low green strength.

Bloating Tests (Quick-Firing): NA

Other Tests: Not effervescent with HCl.

Potential Uses: No designated ceramic use.

LANCASTER COUNTY East Hempfield Twp.

Sample Number
168-8-11

Quadrangle: Lancaster 15′; Lancaster 7½′

Location: Abandoned quarry on the R. H. Getz property on the north side of Spring Valley Road approximately 2,500 feet west of the road intersection with Rohrerstown Road. The quarry is located in a wooded area east of the house located on the north side of a bend in the road.

Geologic Unit: Kinzers Formation, Cambrian

Description: A motted light to medium gray (N5 to N7) shale with indistinct bedding is exposed in the quarry. It has been moderately metamorphosed. There is an intersecting pattern of cleavage and joint planes causing the outcrop to break into fragments. The rock is limonite stained along cleavage and jointing with local limonite boxworks. There is a thin residual soil overburden.

Fossils: Numerous trilobites (Olenellus) and small limonitic molds of undetermined marine animals.

Attitude of Bedding: Indistinct; Cleavage: N45E, steeply dipping.

Sampled Interval: Composite sample of 15 feet of vertical section.

Type of Material: Shale

Ceramic Testing Laboratory: Tuscaloosa

Chemical Analysis:

Analyst: Conwell	%
L.O.I. @ 1,000°C*	4.33
H_2O Loss @ 110°C	0.33
Combined H_2O	4.27
SiO_3	54.16
Al_2O_3	23.18
Fe_2O_3	3.86

Mineralogy (X-ray):

	%	Accuracy (±%)
Quartz	22	6
Mica	70	8
Kaolinite	0	—
C-V-Mo	0	—
Feldspar	2	1

Remarks:

Chemical Analysis:

Analyst: Conwell	%
FeO	2.81
CaO	0.06
MgO	2.11
CO_2	0.00
Na_2O	0.08
K_2O	8.52
TiO_2	0.81
P_2O_5	0.19
MnO	0.01
S (total)	0.02
C (total)	0.30

* Nitrogen atmosphere

Other Properties:

pH: 6.00
P.C.E.: NA
Water of Plasticity (%): 15.4
Drying Shrinkage (%): 0.0
Dry Strength: Low
Drying Characteristics: No drying defects
Workability: Low plasticity

Slow-Firing Tests:

Temp. °F	*Color*	*Hardness*	*% Shk.*	*% Absorb.*	*% App. Por.*	*Approx. Sp. Gr.*
1800	Tan	Poor bond	—	—	—	—
1900	Tan	Moh's 3	0.0	14.0	26.5	1.89
2000	Light brown	Moh's 4	5.0	5.7	12.6	2.21
2100	Dark brown	Moh's 5	7.5	0.8	1.8	2.21
2200	—	—	Melted	—	—	—
2300						

Pyrometric cone equivalent: NA **Bloating test:** Positive

Remarks: Low dry strength; poor ceramic bonds, poor color. Not suitable for use as principle component in vitreous clay products.

Bloating Tests (Quick-Firing):

Crushing characteristics: Angular Particle size ¾" Lumps
Drying characteristics: NA Retention time: 15 minutes

Temp. °F	*Bulk Density*	*Lb/Ft³*	*% Absorb.*	*Remarks*
1800				
1900				
2000	1.09	68	2.3	Fair pore structure
2100	0.85	53	2.6	Good pore structure
2200	0.87	54	2.6	Good pore structure
2300				

Recommendations: Promising raw material for lightweight aggregate.

ROTARY KILN TESTS:

Raw Material:

Screen Analysis (Crushed through a hammermill with 1½" screen)

Size		*Percent Retained*
—¾"	+ ½"	45.0
—½"	+ ⅜"	12.2
—⅜"	+ 4 mesh	18.0
—4 mesh	+ 8 mesh	5.4
—8 mesh	PAN	19.4
	TOTAL	100.0

Crushing loss (—4 mesh) 24.8%

Fragment shape: Platy

Firing Data:

Size range of feed: —¾ + 4 mesh Pour weight of feed: 84.0 lb/ft^3

Bloating temperature: 1960°F

Logging temperature* (*Nodules sticking together): 1990°F

Fired Material (all fired material crushed through a roll crusher)

Screen Analysis* (*ASTM Designation C 311-59T) in percentages by weight passing sieves:

Size designation	¾″	½″	⅜″	No. 4	No. 8	No. 16	No. 50	No. 100
Fine	—	—	100.0	48.5	—	14.5	7.7	6.7
Coarse	100.0	80.0	58.0	18.0	6.8	—	—	—

Loose pour weight* (*ASTM Designation C 311-59T):

Fine: 47.5 lb/ft^3 Coarse: 42.5 lb/ft^3

Color: Light brown

COMMENTS: Best potential for lightweight aggregate; angular and tabular fragments; good crushing; fine pores.

Other Tests: Not effervescent with HCl.

Semi-quantitative spectrographic analysis showed the following abundance of trace elements: Ba(>0.1%), Sr, Zr, and V(>0.001 <0.01%). Other elements such as Zn, Cu, Cr, and Ni, if present, are less than 0.001%.

Potential Uses: Best potential for lightweight aggregate by rotary kiln method.

Remarks: This quarry is in an area of low density residential housing. Approximately ⅜ of a mile northeast of the sampling site is an active quarrying operation in Kinzers shale with the material apparently being used for fill. These quarries are located on opposite sides of the same hill with all the intervening acreage either being wooded or farm fields. However, to the north on the next slope is an extensive recreational establishment with club house, swimming pool and playgrounds. Perhaps future prospecting should be limited to the western extension of this Kenzer's Formation outcrop.

LANCASTER COUNTY Manheim Twp.

Sample Number

168-8-12

Quadrangle: Lancaster 15′; Lancaster 7½′

Location: Outcrop located in the northeast quadrant of Pa. Route 72 cloverleaf exit of Pa. Route 230 bypass.

Geologic Unit: Kinzers Formation, Cambrian

Description: Light to medium gray (N5 to N7) shale in beds up to 0.4 feet thick are exposed in the cloverleaf roadcut. The upper 10 feet of exposed section has been affected by ground creep.

Attitude of Bedding: Obscure—approximate dip, 45°N. Joints: N60W, 68S; N68W, 44S. Cleavage: N5E to 20W, nearly vertical.

Sampled Interval: 25 feet of vertical section.

Type of Material: Shale

Ceramic Testing Laboratory: Tuscaloosa

Chemical Analysis:

Analyst: Conwell	%
L.O.I. @ 1,000°C*	3.96
H_2O Loss @ 110°C	0.38
Combined H_2O	3.78
SiO_2	54.84
Al_2O_3	22.22
Fe_2O_3	4.56
FeO	2.52
CaO	0.06
MgO	2.05
CO_2	0.00
Na_2O	0.07
K_2O	8.34
TiO_2	0.81
P_2O_5	0.15
MnO	0.03
S (total)	0.02
C (total)	0.33

* Nitrogen atmosphere

Mineralogy (X-ray):

	%	*Accuracy* (±%)
Quartz	22	6
Mica	71	7
Kaolinite	0	—
C-V-Mo	0	—
Feldspar	2	1

Remarks:

Other Properties:

pH: 6.6
P.C.E.: NA
Water of Plasticity (%): 15.3
Drying Shrinkage (%): 0.0
Dry Strength: Low
Drying Characteristics: No drying defects
Workability: Low plasticity

Slow-Firing Tests:

Temp. °F	*Color*	*Hardness*	*% Shk.*	*% Absorb.*	*% App. Por.*	*Approx. Sp. Gr.*
1800	Tan	Poor bond	—	—	—	—
1900	Tan	Moh's 2	0.0	13.8	25.8	1.87
2000	Light brown	Moh's 3	5.0	6.4	13.6	2.13
2100	Dark brown	Moh's 5	5.0	4.2	8.8	2.11
2200	Melted	—	—	—	—	—
2300						

Pyrometric cone equivalent: NA **Bloating test:** Positive

Remarks: Low dry strength. Poor ceramic bond. Poor color. Not suitable for use as the principal component in vitreous clay products.

Bloating Tests (Quick-Firing):

Crushing characteristics: Tabular   Particle size ¾" Lumps
Drying characteristics: NA   Retention time: 15 minutes

Temp. °F	*Bulk Density*	*Lb/Ft³*	*% Absorb.*	*Remarks*
1800	—	—	—	
1900	—	—	—	
2000	1.38	86	3.1	Laminar expansion
2100	0.71	44	3.1	Some large pores
2200	0.64	40	4.7	Large pores; vitreous
2300				

Recommendations: Promising raw material for lightweight aggregate.

ROTARY KILN TESTS:

Raw Material:

Screen Analysis (Crushed through a hammermill with 1½" screen)

Size		*Percent Retained*
—¾"	+ ½"	26.1
—½"	+ ⅜"	18.1
—⅜"	+ 4 mesh	23.5
—4 mesh	+ 8 mesh	3.9
—8 Mesh	PAN	28.4
	TOTAL	100.0

Crushing loss (—4 mesh) 32.3%

Fragment shape: Angular

Firing Data:

Size range of feed: —¾ + 4 mesh

Pour weight of feed: 84.0 lb/ft^3

Bloating temperature: 1990°F

Logging temperature* (*Nodules sticking together): 2040°F

Fired Material (all fired material crushed through a roll crusher)

Screen Analysis* (*ASTM Designation C 311-59T) in percentages by weight passing sieves:

Size designation	¾"	½"	⅜"	No. 4	No. 8	No. 16	No. 50	No. 100
Fine	—	—	100.0	60.0	—	22.0	12.0	9.4
Coarse	100.0	91.0	67.0	11.0	4.0	—	—	—

Loose pour weight* (*ASTM Designation C 311-59T):

Fine: 50.0 lb/ft^3 Coarse: 35.0 lb/ft^3

Color: Light brown

COMMENTS: Best potential for lightweight aggregate; angular fragments; excellent pore structure; good crushing.

Other Tests: Not effervescent with HCl.

Semi-quantitative spectrographic analysis showed the following abundance of trace elements: Ba (>0.1%), Sr, Zr, and V (>0.001<0.01%). Other elements such as Zn, Cu, Cr, and V, Ni, if present, are less than 0.001%.

Potential Uses: Best potential for lightweight aggregate.

LANCASTER COUNTY Paradise Twp.

Sample Number
178-8-5

Quadrangle: New Holland 15'; New Holland 7½'

Location: Kinzers shale exposures on the south side of the Penn. Central Railroad Co. main-line railroad cut at the west edge of Vintage, Pa.

Geologic Unit: Kinzers Formation, Cambrian

Description: This exposure is described in the Lancaster Quadrangle, Pennsylvania Geological Survey Atlas No. 168, page 24. A graphitic to phyllitic, medium light gray (N 6.5), moderately weathered shale is exposed in the railroad cut. The shale is somewhat shistose in places with light limonite staining along cleavages. About 8 feet of vertical section were sampled on a grassy embankment in which several small outcrops (2x3 feet) are exposed. The sample classified as a general grab sample.

Attitude of Bedding:

Sampled Interval: Grab sample of approximately 8 feet of vertical section on the embankment.

Type of Material: Shale, graphitic and phyllitic

Ceramic Testing Laboratory: Tuscaloosa

Chemical Analysis:

Analyst: Conwell	%
L.O.I. @ 1,000°C*	7.03
H_2O Loss @ 110°C	0.18
Combined H_2O	6.82
SiO_2	54.68
Al_2O_3	22.54
Fe_2O_3	4.25
FeO	1.26
CaO	0.03
MgO	2.31
CO_2	0.00
Na_2O	0.10
K_2O	6.12
TiO_2	0.85
P_2O_5	0.02
MnO	0.01
S (total)	0.01
C (total)	0.63

* Nitrogen atmosphere

Mineralogy (X-ray):

	%	Accuracy (±%)
Quartz	27	5
Mica	59	6
Kaolinite	0	—
C-V-Mo	0	—
Feldspar	9	3

Remarks:

Other Properties:

pH: 5.5
P.C.E.: NA
Water of Plasticity (%): 21.1
Drying Shrinkage (%): 0.0
Dry Strength: Low
Drying Characteristics: No drying defects
Workability: Low plasticity

Slow-Firing Tests:

Temp. °F	*Color*	*Hardness*	*% Shk.*	*% Absorb.*	*% App. Por.*	*Approx. Sp. Gr.*
1800	Tan	Poor bond	—	—	—	—
1900	Tan	Poor bond	—	—	—	—
2000	Light brown	Moh's 3	2.5	15.2	27.4	1.80
2100	Dark brown	Moh's 4	7.5	5.9	10.7	1.81
2200	Melted	—	—	—	—	—
2300						

Pyrometric cone equivalent: NA **Bloating test:** Positive

Remarks: Low dry strength. Poor ceramic bond. Poor color. Not suitable for use as principle component in vitreous clay products.

Bloating Tests (Quick-Firing):

Crushing characteristics: Tabular Particle size: ¾" lumps
Drying characteristics: NA Retention time: 15 minutes

Temp. °F	*Bulk Density*	*Lb/Ft³*	*% Absorb.*	*Remarks*
1800				
1900				
2000	1.59	99	7.2	No expansion
2100	0.87	54	7.6	Fair pore structure
2200	0.81	51	6.6	Good pore structure
2300				

Recommendations: Promising raw material for lightweight aggregate.

ROTARY KILN TESTS:

Raw Material:

Screen Analysis (Crushed through a hammermill with 1½" screen)

Size		Percent Retained
—¾"	+ ½"	18.3
—½"	+ ⅜"	12.8
—⅜"	+ 4 mesh	23.0
—4 mesh	+ 8 mesh	10.0
—8 mesh	PAN	35.9
	TOTAL	100.0

Crushing loss (—4 mesh) 45.9%

Fragment shape: Angular and platy

Firing Data:

Size range of feed: —¾ + 4 mesh   Pour weight of feed: 97.0 lb/ft^3

Bloating temperature: 1980°F

Logging temperature* (*Nodules sticking together): 2040°F

Fired Material (all fired material crushed through a roll crusher)

Screen Analysis* (*ASTM Designation C 311-59T) in percentages by weight passing sieves:

Size designation	¾"	½"	⅜"	No. 4	No. 8	No. 16	No. 50	No. 100
Fine	—	—	100.0	79.0	—	53.0	33.0	17.0
Coarse	100.0	79.0	57.0	20.0	13.6	—	—	—

Loose pour weight* (*ASTM Designation C 311-59T):

Fine: 65.0 lb/ft^3 Coarse: 60.0 lb/ft^3

Color: Tan

COMMENTS: Marginal for lightweight aggregate. Undesirable mixture of bloating and non-bloating materials; angular fragments; good pore structure; poor crushing; some non-bloating material.

Other Tests: Not effervescent with HCl.

Semi-quantitative analysis showed the following abundance for trace elements: Ba (>0.1%), Sr, Zr, and V (>0.001 <0.01%). Other elements such as Zn, Cu, and Ni, if present, are less than 0.001%.

Potential Uses: Rotary kiln tests suggest this material will make fair quality lightweight aggregate at best.

Remarks: The bulk sample for rotary kiln testing was collected by extensive digging at all the small outcrops used for the preliminary sample to expose fresher material and a thicker section of bedded material collected at each station. Each station was channel sampled and weighted according to the proportionate part of the 8 feet of section it represented.

LEBANON COUNTY Union Twp.

Sample Number
137-3-5

Quadrangle: Hummelstown 15′; Indiantown Gap 7½′

Location: Exposure along the southeast side of Pa. Route 443, about 0.5 mile northeast of Green Point, Pa.

Geologic Unit: Mahantango Formation, Devonian

Description: Interbedded, pale-yellow orange and grayish orange, thin-bedded shales and siltstones are exposed for a distance of about 100 feet along the roadway. Weathering is moderate to intense. The height of the exposure is about 18 feet.

Attitude of Bedding: Approximately N45E, no dip was recorded.

Sampled Interval: Channel sample of 20 stratigraphic feet.

Type of Material: Shale and siltstone

Ceramic Testing Laboratory: Norris

Chemical Analysis:

Analyst: Spectrochemical

	%
L.O.I. @ 1,000°C	4.13
H_2O Loss @ 110°C	0.38
Combined H_2O	NA
SiO_2	75.80
Al_2O_3	10.00
Fe_2O_3	4.33
FeO	0.76
CaO	0.31
MgO	0.76
CO_2	0.55
Na_2O	0.46
K_2O	2.30
TiO_2	1.06
P_2O_5	NA
MnO	NA
S (total)	<0.04
C (total)	0.26

Mineralogy (X-ray):

	%	Accuracy (±%)
Quartz	54	5
Mica	24	6
Kaolinite	8	7
C-V-Mo	7	3
Feldspar	2	1

Remarks: Mineralogy indicates chemical analysis is low in Al_2O_3.

Other Properties:

pH: 6.65
P.C.E.: NA
Water of Plasticity (%): 19.0
Drying Shrinkage (%): 0.5
Dry Strength: Good
Drying Characteristics: Fair; wavy; surface cracks
Workability: Short-working, fine-grit

Slow-Firing Tests:

Temp. °F	Color	Hardness	% Shk.	% Absorb.	% App. Por.	Approx. Sp. Gr.
1800	Lt. red brown	Fair hard	1.0	4.5	—	2.52
1900	Lt. red brown	Fair hard	1.0	4.7	—	2.53
2000	Reddish brown	Hard	5.0	4.8	—	2.52
2100	Brown	Hard	5.0	5.7	—	2.45
2200	Dark brown	Very hard	7.5	8.5	—	2.26
2300	Black-brown	Very hard	2.1	11.3	—	1.50

Pyrometric cone equivalent: NA **Bloating test:** Negative

Remarks: Fair color; surface wavy and slightly rough; absorption a little high; very slight scum or spotting. Addition of alkali might improve ceramic properties. Slight bloating and then fusion (melting) within 25°F. range.

Other Tests: Soluble Br. K. 1.10

Potential Uses: Face brick (slight bloating and then fusion within 25°F range), providing alkali is used to control scum and spotting, and color of finished ware is acceptable.

LEBANON COUNTY Bethel Twp.

Sample Number
167-1-5

Quadrangle: Lebanon 15′; Fredericksburg 7½′

Location: Quarry about 0.6 mile south-southeast of the center of Fredericksburg, Pa., and 800 feet west of Pa. Route 343.

Geologic Unit: Martinsburg Formation, Ordovician

Description: Gray red (10 R 4/2), thin-bedded, platy shale is exposed for a distance of 70 feet in a quarry which is a maximum of about 25 feet high. The shale is slightly to very slightly weathered.

Attitude of Bedding: N80E, 85S

Sampled Interval: Grab sample from eastern portion of quarry.

Type of Material: Shale

Ceramic Testing Laboratory: Norris

Chemical Analysis:

Analyst: Spectrochemical	%
L.O.I. @ 1,000°C	5.22
H_2O Loss @ 110°C	0.40
Combined H_2O	NA
SiO_2	66.60
Al_2O_3	12.50
Fe_2O_3	6.42
FeO	0.45
CaO	1.80
MgO	1.88
CO_2	1.91
Na_2O	0.71
K_2O	3.50
TiO_2	0.86
P_2O_5	NA
MnO	NA
S (total)	> 0.03
C (total)	0.09

Mineralogy (X-ray):

	%	Accuracy (±%)
Quartz	30	5
Mica	49	6
Kaolinite	5	3
C-V-Mo	9	3
Feldspar	2	1

Remarks: Mineralogy indicates chemical analysis is low in Al_2O_3.

Other Properties:

pH: 7.40
P.C.E.: NA
Water of Plasticity (%): 16.0
Drying Shrinkage (%): 1.0
Dry Strength: Fair
Drying Characteristics: Poor; rough; cracks; wavy
Workability: Mealy; short-working

Slow-Firing Tests:

Temp. °F	Color	Hardness	% Shk.	% Absorb.	% App. Por.	Approx. Sp. Gr.
1800	Light brown	Fair hard	4.0	7.6	—	2.55
1900	Light brown	Hard	4.0	9.0	—	2.51
2000	Brown	Very hard	6.5	14.1	—	2.48
2100	Chocolate	Very hard	6.5	28.0	—	2.26
2200	Dark brown	Hard	Expanded	13.7	—	0.83
2300						

Pyrometric cone equivalent: NA **Bloating test:** Positive

Remarks: Fair color; high absorption; rough surface; expands.

Bloating Tests (Quick-Firing):

Crushing characteristics: Good — Particle size: —¾" + ½"
Drying characteristics: Good — Retention time: 15 minutes

Temp. °F	*Bulk Density*	*Lb/Ft³*	*% Absorb.*	*Remarks*
1800	—	—	—	
1900	—	—	—	
2000	1.78	111	44.6	Slightly uneven expansion
2100	1.67	104	44.2	Spotty expansion
2200	1.47	92	10.9	Spotty shaly expansion
2300				

Recommendations: Rather heavy for lightweight aggregate.

Other Tests: None

Potential Uses: Possibly fair quality lightweight aggregate.

Remarks: A six-inch gas line is located about 0.25 mile east of this quarry and sampling site for Sample 167-1-1 (see O'Neill and others 1965, page 246). Sample 167-1-1 has potential use as raw material for brick, tile, and lightweight aggregate; but Sample 167-1-5, on the other hand, is not considered too desirable for any of these uses.

LEBANON COUNTY Swatara Twp.

Sample Number
167-1-6

Quadrangle: Lebanon 15', Fredericksburg 7½'

Location: Exposure on the east side of a macadam road leading north from Jonestown, Pa. The exposure is about 0.2 mile, extending from 1 mile north of Jonestown to within a few hundred feet of Groff School.

Geologic Unit: Martinsburg Formation, Ordovician

Description: A slightly weathered, alternating dark-red brown (10 R 3/4) and dark-yellow orange (10 YR 6/6), very thin-bedded shale sequence is exposed for a distance of 1200 feet along the roadway. A few yellow siltstone beds are interbedded with the shales. The exposure is a maximum of 10 feet high.

Attitude of Bedding: N50-60E, 40S; strikes and dips vary due to folding.

Sampled Interval: Grab sample of the northermost 500 feet of the exposure.

Type of Material: Shale

Ceramic Testing Laboratory: Norris

Chemical Analysis:

Analyst: Spectrochemical	%
L.O.I. @ 1,000°C	5.19
H_2O Loss @ 110°C	0.80
Combined H_2O	NA
SiO_2	65.60
Al_2O_3	14.70
Fe_2O_3	7.60
FeO	0.42

Mineralogy (X-ray):

	%	*Accuracy (±%)*
Quartz	37	5
Mica	44	6
Kaolinite	4	3
C-V-Mo	8	3
Feldspar	2	1

Remarks: Mineralogy indicates chemical analysis is low in Al_2O_3.

Chemical Analysis:

Analyst: Spectrochemical %

CaO	0.38
MgO	0.99
CO_2	0.59
Na_2O	0.44
K_2O	3.70
TiO_2	0.92
P_2O_5	NA
MnO	NA
S (total)	< 0.03
C (total)	0.14

Other Properties:

pH: 6.00
P.C.E.: NA
Water of Plasticity (%): 20.0
Drying Shrinkage (%): 0.0
Dry Strength: Fair
Drying Characteristics: Fair, slightly rough; warping
Workability: Mealy; fatty; short-working

Slow-Firing Tests:

Temp. °F	*Color*	*Hardness*	*% Shk.*	*% Absorb.*	*% App. Por.*	*Approx. Sp. Gr.*
1800	Light brown	Fair hard	1.0	6.2	—	2.63
1900	Light brown	Fair hard	5.0	7.4	—	2.57
2000	Brown	Hard	5.0	9.8	—	2.52
2100	Chocolate	Very hard	7.5	14.6	—	2.47
2200	Dark brown	Very hard	4.5	19.9	—	2.00
2300	Black-brown	Hard	0.5	15.2	—	1.34

Pyrometric cone equivalent: NA **Bloating test:** Positive

Remarks: Fair color; high absorption; rough and wavy surface; expands; slow-firing. Tests indicate possible use as lightweight aggregate.

Bloating Tests (Quick-Firing):

Crushing characteristics: Fair-shaly Particle size: —¾″ + ½″
Drying characteristics: Good Retention time: 15 minutes

Temp. °F	*Bulk Density*	*Lb/Ft³*	*% Absorb.*	*Remarks*
1800	—	—	—	
1900	—	—	—	
2000	2.40	150	35.8	Spotty expansion
2100	2.43	151	24.3	Spotty expansion
2200	1.46	91	20.5	Spotty expansion
2300				

Recommendations: Rather heavy for lightweight aggregate.

ROTARY KILN TESTS:

Raw Material:

Screen Analysis (Crushed through a hammermill with 1½″ screen)

Size		*Percent Retained*
—¾″	+ ½″	41.3
—½″	+ ⅜″	21.0
—⅜″	+ 4 mesh	26.3
—4 mesh	+ 8 mesh	10.2
—8 mesh	PAN	1.2
	TOTAL	100.0

Crushing loss (—4 mesh) 11.4%

Fragment shape: Tabular fragments

Firing Data:

Size range of feed: —¾ + 4 mesh   Pour weight of feed: 79.4 lb/ft³

Bloating temperature: 2100°F

Logging temperature* (*Nodules sticking together): 2150°F

Fired Material (all fired material crushed through a roll crusher)

Screen Analysis* (*ASTM Designation C 311-59T) in percentages by weight passing sieves:

Size designation	¾"	½"	⅜"	No. 4	No. 8	No. 16	No. 50	No. 100
Fine	—	—	100.0	51.5	—	6.2	1.2	0.6
Coarse	100.0	93.8	67.8	24.2	5.5	—	—	—

Loose pour weight* (*ASTM Designation C 311-59T):

Fine: 67.0 lb/ft³   Coarse: 64.0 lb/ft³

Color: Dark brown

COMMENTS: Sample failed to meet ASTM weight specifications; bloating temperature too high; tabular and angular fragments; mostly nonporous; poor crushing.

Other Tests: Soluble Br. K. 0.75

Potential Uses: No designated ceramic use.

Remarks: Tests for sample 167-1-2 indicated that the material was good for lightweight aggregate, brick, and tile (see O'Neill and others 1965, p. 248-249). Tests for Sample 167-1-6 indicate that it failed to meet ASTM weight specification for lightweight aggregate and other ceramic uses.

LEBANON COUNTY Swatara Twp.

Sample Number
167-1-7

Quadrangle: Lebanon 15', Fredericksburg 7½'

Location: Exposure 2.3 miles east of Pa. Route 72 at the intersection of U.S. Route 22 and improved road leading northeast into Fredericksburg, Pa.

Geologic Unit: Martinsburg Formation, Ordovician

Description: Grayish-red (10 R 4/2) to grayish-orange (10 YR 7/4), fresh to moderately weathered shale is exposed in a road cut 100 feet long and 10 feet high.

Attitude of Bedding: Not measured

Sampled Interval: Composite sample of outcrop

Type of Material: Shale

Ceramic Testing Laboratory: Tuscaloosa

Chemical Analysis:

Analyst: Conwell	%
L.O.I. @ 1,000°C	4.80
H_2O Loss @ 110°C	0.86
Combined H_2O	4.94

Mineralogy (X-ray):

	%	*Accuracy* (±%)
Quartz	22	5
Mica	67	8
Kaolinite	0	—

Chemical Analysis:

Analyst: Conwell

	%
SiO_2	56.54
Al_2O_3	21.80
Fe_2O_3	7.82
FeO	0.22
CaO	0.20
MgO	1.34
CO_2	0.57
Na_2O	0.04
K_2O	4.20
TiO_2	1.27
P_2O_5	NA
MnO	NA
S (total)	None
C (total)	0.02

Mineralogy (X-ray):

	%	Accuracy (±%)
C-V-Mo	0	—
Feldspar	1	1

Remarks:

Other Properties:

pH: 6.30
P.C.E.: NA
Water of Plasticity (%): 19.6
Drying Shrinkage (%): 2.5
Dry Strength: Low
Drying Characteristics: No defects
Workability: Low plasticity

Slow-Firing Tests:

Temp. °F	*Color*	*Hardness*	*% Shk.*	*% Absorb.*	*% App. Por.*	*Approx. Sp. Gr.*
1800	Light brown	Moh's 2	2.5	10.6	21.7	2.05
1900	Light brown	Moh's 3	2.5	6.2	13.7	2.21
2000	Brown	Moh's 3	7.5	3.9	9.1	2.34
2100	Red-brown	Moh's 4	10.0	0.6	1.5	2.51
2200	Red-brown	Moh's 5	12.5	0.6	1.4	2.41
2300	Dark brown	Moh's 6	12.5	0.6	1.4	2.39

Pyrometric cone equivalent: NA **Bloating test:** Negative

Remarks:

Bloating Tests (Quick-Firing): NA

Other Tests: Not effervescent with HCl.

Potential Uses: Should fire to quarry tile specifications at about 2050°F.

LEHIGH COUNTY Lynn Twp.

Sample Number
186-3-7

Quadrangle: Hamburg 15′, New Tripoli 7½′

Location: Waste slate dump and quarry on the northwest side of Pa. Route 143 located about 1 mile northeast of Lynnport, Pa.

Geologic Unit: Martinsburg Formation, Upper Soft Slate Member; Ordovician

Description: Medium gray to medium-dark gray slate was sampled from the waste dump of the former Kuntz Quarry. The slate is slightly weathered with the exposed fragments commonly stained pale to moderate yellow brown. The fragments are usually irregular in shape and average from one to two feet in length. Some of the fragments are sandy. The quarry is 70 feet by 150 feet and is filled with water; no depth measurement was possible.

Attitude of Bedding: Not recognizable; **Attitude of Cleavage:** N55E, 62S.

Sampled Interval: Grab sample from waste dump.

Type of Material: Slate

Ceramic Testing Laboratory: Tuscaloosa

Chemical Analysis:

Analyst: Conwell	%
L.O.I @ 1,000°C	8.78
H_2O Loss @ 110°C	0.37
Combined H_2O	3.83
SiO_2	55.36
Al_2O_3	17.05
Fe_2O_3	0.37
FeO	3.96
CaO	6.05
MgO	2.86
CO_2	4.59
Na_2O	1.03
K_2O	2.40
TiO_2	0.72
P_2O_5	NA
MnO	NA
S (total)	0.61
C (total)	0.47

Mineralogy (X-ray):

	%	*Accuracy* (±%)
Quartz	28	6
Mica	35	8
Kaolinite	22	7
C-V-Mo	8	3
Feldspar	2	1

Remarks: Carbonate present.

Other Properties:

pH: 7.50
P.C.E.: NA
Water of Plasticity (%): 18.5
Drying Shrinkage (%): 2.5
Dry Strength: Low
Drying Characteristics: No drying defects
Workability: Low plasticity

Slow-Firing Tests:

Temp. °F	*Color*	*Hardness*	*% Shk.*	*% Absorb.*	*% App. Por.*	*Approx. Sp. Gr.*
1800	Beige	Moh's 3	2.5	18.3	—	1.75
1900	Beige	Moh's 4	2.5	16.9	—	1.78
2000	Beige	Moh's 5	2.5	16.3	—	1.78
2100	Brown	Moh's 6	2.5	2.0	—	1.60
2200	—	—	Expanded	—	—	—
2300						

Pyrometric cone equivalent: NA **Bloating test:** Positive

Remarks: Poor color; short vitrification range.

Bloating Tests (Quick-Firing):

Crushing characteristics: Platy Particle size: —¾″ + ½″
Drying characteristics: — Retention time: 15 minutes

Temp. °F	*Bulk Density*	*Lb/Ft³*	*% Absorb.*	*Remarks*
1800				
1900	1.49	93	10.6	No bloating
2000	0.63	39	13.1	Good pore structure
2100	0.39	24	24.1	Poor pore structure; melting
2200				
2300				

Recommendations: Trial run in rotary kiln should be made.

ROTARY KILN TESTS:

Raw Material:

Screen Analysis (Crushed through a hammermill with 1½" screen)

Size		Percent Retained
—¾"	+ ½"	19.5
—½"	+ ⅜"	13.8
—⅜"	+ 4 mesh	32.9
—4 mesh	+ 8 mesh	20.3
—8 mesh	PAN	13.5
	TOTAL	100.0

Crushing loss (—4 mesh) 33.8%

Fragment shape: Thin plates

Firing Data:

Size range of feed: —¾ + 4 mesh Pour weight of feed: 90.4 lb/ft^3

Bloating temperature: 1980°F

Logging temperature* (*Nodules sticking together): 1990°F

Fired Material (all fired material crushed through a roll crusher)

Screen Analysis* (*ASTM Designation C 311-59T) in percentages by weight passing sieves:

Size designation	¾"	½"	⅜"	No. 4	No. 8	No. 16	No. 50	No. 100
Fine	—	—	100.0	81.2	—	19.8	6.1	3.9
Coarse	100.0	91.2	77.1	42.0	11.4	—	—	—

Loose pour weight* (*ASTM Designation C 311-59T):

Fine: 65.0 lb/ft^3 Coarse: 62.5 lb/ft^3

Color: Gray

COMMENTS: Failed to meet ASTM weight specifications for coarse aggregate; excessive crushing loss of raw material; short-firing range; undesirable fragment shape of fired product (thin plates); thin plates; liminar expansion; unsatisfactory crushing characteristics.

Other Tests: Highly effervescent in HCl.

Potential Uses: No designated ceramic use.

LEHIGH COUNTY Lynn Twp.

Sample Number
186-5-8

Quadrangle: Hanover 15′; Tripoli 7½′

Location: The westernmost quarry and waste slate dump in Slateville, Pa., on the northwest side of the macadam road between Slateville and Quaker City, Pa. The quarry is referred to as the Old Daniel's Quarry.

Geologic Unit: Martinsburg Formation, Upper Soft Slate Member, Ordovician.

Description: Medium gray to medium-dark gray slate with a bluish tinge was sampled from the waste dump south of the Old Daniel's Quarry. The fragments are irregular in shape and generally average more than a foot in length. The quarry is irregular in shape, measuring about 140 by 275 feet in plan and is reported to be 125 feet deep.

Attitude of Bedding: An anticline and syncline are exposed in the southwest wall of the quarry.

Sampled Interval: Grab sample from the waste dump.

Type of Material: Slate

Ceramic Testing Laboratory: Tuscaloosa

Chemical Analysis:

Analyst: Conwell	%
L.O.I. @ 1,000°C	7.05
H_2O Loss @ 110°C	0.20
Combined H_2O	4.65
SiO_2	59.30
Al_2O_3	17.53
Fe_2O_3	0.03
FeO	4.46
CaO	4.03
MgO	2.33
CO_2	3.08
Na_2O	1.03
K_2O	2.64
TiO_2	0.73
P_2O_5	NA
MnO	NA
S (total)	0.40
C (total)	0.58

Mineralogy (X-ray):

	%	Accuracy (±%)
Quartz	30	5
Mica	32	6
Kaolinite	18	7
C-V-Mo	8	3
Feldspar	2	1

Remarks: Carbonate present.

Other Properties:

pH: 9.00
P.C.E.: NA
Water of Plasticity (%): 20.3
Drying Shrinkage (%): 2.5
Dry Strength: Low
Drying Characteristics: No drying defects
Workability: Low plasticity

Slow-Firing Tests:

Temp. °F	*Color*	*Hardness*	*% Shk.*	*% Absorb.*	*% App. Por.*	*Approx. Sp. Gr.*
1800	Beige	Moh's 3	2.5	19.1	—	1.72
1900	Beige	Moh's 4	2.5	18.2	—	1.73
2000	Beige	Moh's 5	2.5	16.4	—	1.76
2100	Brown	Moh's 6	2.5	1.3	—	1.84
2200	—	—	Expanded	—	—	—
2300						

Pyrometric cone equivalent: NA **Bloating test:** Positive

Remarks: Poor color; short vitrification range

Bloating Tests (Quick-Firing):

Crushing characteristics: Platy — Particle size: —¾″ + ½″
Drying characteristics: NA — Retention time: 15 minutes

Temp. °F	*Bulk Density*	*Lb/Ft³*	*% Absorb.*	*Remarks*
1800				
1900	1.39	87	13.5	No bloating
2000	0.82	51	8.9	Fair pore structure; laminar
2100	0.51	32	25.6	Poor pore structure; melting
2200				
2300				

Recommendations: Trial run in rotary kiln should be made.

ROTARY KILN TESTS:

Raw Material:

Screen Analysis (Crushed through a hammermill with 1½" screen)

Size		Percent Retained
—¾"	+ ½"	20.8
—½"	+ ⅜"	12.4
—⅜"	+ 4 mesh	30.4
—4 mesh	+ 8 mesh	23.3
—8 mesh	PAN	13.1
	TOTAL	100.0

Crushing loss (—4 mesh) 36.7%

Fragment shape: Tabular fragments and thin plates.

Firing Data:

Size range of feed: —¾ + 4 mesh

Pour weight of feed: 86.0 lb/ft³

Bloating temperature: 1870°F

Logging temperature* (*Nodules sticking together): 1880°F

Fired Material (all fired material crushed through a roll crusher)

Screen Analysis* (*ASTM Designation C 311-59T) in percentages by weight passing sieves:

Size designation	¾"	½"	⅜"	No. 4	No. 8	No. 16	No. 50	No. 100
Fine	—	—	100.0	68.9	—	13.5	5.0	3.4
Coarse	100.0	91.2	77.6	42.1	10.3	—	—	—

Loose pour weight* (*ASTM Designation C 311-59T):

Fine: 53.1 lb/ft³ Coarse: 50.0 lb/ft³

Color: Gray

COMMENTS: Excessive crushing loss of raw material; short firing range; undesirable fragment shape of fired product (thin plates); mostly thin plates; laminar expansion; poor crushing.

Other Tests: Highly effervescent in HCl.

Potential Uses: Rotary kiln tests indicate this material will not make a good lightweight aggregate. Probably a fair quality lightweight aggregate could be produced at best.

LEHIGH COUNTY Lynn Twp.

Sample Number

186-6-4

Quadrangle: Hamburg 15′, New Tripoli 7½′

Location: Road exposure 1.25 miles south of the center of New Tripoli, Pa., along the east side of the road between New Tripoli and Lynnville, Pa.

Geologic Unit: Martinsburg Formation, Ordovician.

Description: Interbedded, thin-bedded, light-olive gray to greenish gray, moderately weathered shales and siltstones are exposed for a distance of 550 feet along the roadway. Fragments of the rock are platy to tabular and range from less than one inch to more than six inches in length. The exposure is 10 feet high.

Attitude of Bedding: N65E, 40S; dips are steeper at the north end of the exposure.

Sampled Interval: Grab sample collected along the southernmost 250 feet of the exposure.

Type of Material: Shale and siltstone

Ceramic Testing Laboratory: Norris

Chemical Analysis:

Analyst: Spectrochemical %

L.O.I. @ 1,000°C	3.91
H_2O Loss @ 110°C	0.30
Combined H_2O	NA
SiO_2	73.35
Al_2O_3	9.60
Fe_2O_3	5.29
FeO	1.62
CaO	0.47
MgO	1.43
CO_2	ND
Na_2O	1.06
K_2O	2.50
TiO_2	0.73
P_2O_5	NA
MnO	NA
S (total)	> 0.01
C (total)	0.07

Mineralogy (X-ray):

	%	Accuracy (±%)
Quartz	30	7
Mica	47	7
Kaolinite	7	6
C-V-Mo	6	3
Feldspar	5	2

Remarks: Mineralogy indicates chemical analysis is low in Al_2O_3.

Other Properties:

pH: 7.30
P.C.E.: NA
Water of Plasticity (%): 21.0
Drying Shrinkage (%): 0.0
Dry Strength: Fair
Drying Characteristics: Good; slight warping
Workability: Mealy; gritty; short-working

Slow-Firing Tests:

Temp. °F	Color	Hardness	% Shk.	% Absorb.	% App. Por.	Approx. Sp. Gr.
1800	Tan	Soft	0.0	5.0	—	2.50
1900	Tan	Fair hard	0.0	5.9	—	2.44
2000	Light red brown	Fair hard	2.0	8.6	—	2.41
2100	Red brown	Hard	5.0	12.1	—	2.39
2200	Very dark brown	Very hard	8.0	38.5	—	2.19
2300	Melted	—	—	—	—	—

Pyrometric cone equivalent: NA **Bloating test:** Positive

Remarks: Fair color; warping; absorption a little high; slight scum.

Bloating Tests (Quick-Firing):

Crushing characteristics: Good Particle size: —¾″ + ½″
Drying characteristics: Good Retention time: 15 minutes

Temp. °F	Bulk Density	Lb/Ft³	% Absorb.	Remarks
1800				
1900	2.13	122	11.0	Very slight layered expansion
2000	1.28	79	15.7	Fair expansion, layered expansion
2100	0.72	44	8.0	Fine expansion, fair skin
2200				
2300				

Recommendations: Should make a good lightweight aggregate.

ROTARY KILN TESTS:

Raw Material:

Screen Analysis (Crushed through a hammermill with 1½" screen)

Size		Percent Retained
—¾"	+ ½"	33.8
—½"	+ ⅜"	15.3
—⅜"	+ 4 mesh	25.3
—4 mesh	+ 8 mesh	10.4
—8 mesh	PAN	15.2
	TOTAL	100.0

Crushing loss (—4 mesh) 25.6%

Fragment shape: Tabular fragments

Firing Data:

Size range of feed: —¾ + 4 mesh Pour weight of feed: 81.6 lb/ft³

Bloating temperature: 2080°F

Logging temperature* (*Nodules sticking together): 2100°F

Fired Material (all fired material crushed through a roll crusher)

Screen Analysis* (*ASTM Designation C 311-59T) in percentages by weight passing sieves:

Size designation	¾"	½"	⅜"	No. 4	No. 8	No. 16	No. 50	No. 100
Fine	—	—	100.0	53.7	—	7.1	2.4	1.4
Coarse	100.0	88.3	74.2	35.5	12.0	—	—	—

Loose pour weight* (*ASTM Designation C 311-59T):

Fine: 46.0 lb/ft³ Coarse: 44.5 lb/ft³

Color: Dark brown

COMMENTS: Undesirable fragment shape of fired product (flakes); tabular and thin plates; fair pore structure; poor crushing.

Other Tests: Soluble Br. K. 1.15

Potential Uses: NW Grade facebrick; rotary kiln tests indicate the material will produce a low density fired product, but other factors indicate only fair quality lightweight aggregate could be produced from this raw material.

LEHIGH COUNTY Lynn Twp.

Sample Number

186-6-5

Quadrangle: Hamburg 15'; New Tripoli 7½'

Location: Quarry on the south side of the road between Lynnville and Kempton, Pa., about 1.1 miles west of Lynnville, Pa.

Geologic Unit: Martinsburg Formation, Ordovician

Description: Interbedded, thin-bedded, light olive-gray to olive-gray shales and siltstones are exposed in a quarry measuring about 75 feet by 75 feet and 50 feet high. Rock fragments on the slopes and quarry floor are commonly tabular and range from several inches to more than a foot in length.

Attitude of Bedding: N85E, 65S

Sampled Interval: Composite sample of 25 stratigraphic feet.

Type of Material: Shales and silty shales

Ceramic Testing Laboratory: Norris

Chemical Analysis:

Analyst: Spectrochemical %

L.O.I. @ 1,000°C	5.20
H_2O Loss @ 110°C	0.73
Combined H_2O	NA
SiO_2	64.40
Al_2O_3	15.40
Fe_2O_3	7.09
FeO	1.21
CaO	0.40
MgO	1.39
CO_2	ND
Na_2O	0.70
K_2O	3.20
TiO_2	0.92
P_2O_5	NA
MnO	NA
S (total)	> 0.01
C (total)	0.22

Mineralogy (X-ray):

	%	*Accuracy* (±%)
Quartz	31	8
Mica	47	7
Kaolinite	5	3
C-V-Mo	10	3
Feldspar	2	1

Remarks: Mineralogy indicates chemical analysis is low in Al_2O_3.

Other Properties:

pH: 7.30
P.C.E.: NA
Water of Plasticity (%): 20.6
Drying Shrinkage (%): 0.0
Dry Strength: Good
Drying Characteristics: Good; slight warping
Workability: Mealy; gritty; smooth; short-working

Slow-Firing Tests:

Temp. °F	*Color*	*Hardness*	*% Shk.*	*% Absorb.*	*% App. Por.*	*Approx. Sp. Gr.*
1800	Light tan	Fair hard	0.0	5.1	—	2.57
1900	Red tan	Fair hard	4.0	6.7	—	2.53
2000	Light red tan	Hard	5.0	12.7	—	2.46
2100	Brown	Very hard	6.0	21.3	—	2.42
2200	Dark brown	Steel hard	10.0	60.4	—	2.26
2300						

Pyrometric cone equivalent: NA **Bloating test:** Negative

Remarks: Good color; absorption a little high. Addition of alkali would improve workability.

Bloating Tests (Quick-Firing): NA

Other Tests: Soluble Br. K. 0.60

Potential Uses: Face brick and tile (might require waterproofing).

LEHIGH COUNTY **Weisenberg Twp.**

Sample Number
196-5-3

Quadrangle: Albertis 15′

Location: Small quarry 0.5 mile south of Claussville, Pa., on the east side of an unpaved road leading south from Claussville, Pa.

Geologic Unit: Martinsburg Formation, Lower Hard Slate Member, Ordovician

Description: Medium-gray to medium-dark gray, slightly weathered slate is exposed in the lower part of the southern end of a small quarry. The slate exposed in other parts of the quarry is moderately weathered and tan to buff in color. The slate is tightly folded and cleavage is well developed. The quarry dimensions are approximately 50 x 50 x 40 feet.

Attitude of Bedding: Variable due to folding

Sampled Interval: Composite sample of 20 stratigraphic feet.

Type of Material: Slate

Ceramic Testing Laboratory: Tuscaloosa

Chemical Analysis:

Analyst: Conwell	%
L.O.I. @ 1,000°C	4.32
H_2O Loss @ 110°C	0.15
Combined H_2O	4.10
SiO_2	63.50
Al_2O_3	16.73
Fe_2O_3	3.42
FeO	3.60
CaO	0.40
MgO	2.91
CO_2	0.12
Na_2O	1.08
K_2O	3.36
TiO_2	0.75
P_2O_5	NA
MnO	NA
S (total)	None
C (total)	0.57

Mineralogy (X-ray):

	%	Accuracy (±%)
Quartz	34	5
Mica	33	6
Kaolinite	17	7
C-V-Mo	9	3
Feldspar	2	1

Remarks:

Other Properties:

pH: 8.00
P.C.E.: NA
Water of Plasticity (%): 20.0
Drying Shrinkage (%): 2.5
Dry Strength: Low
Drying Characteristics: No drying defects
Workability: Low plasticity

Slow-Firing Tests:

Temp. °F	Color	Hardness	% Shk.	% Absorb.	% App. Por.	Approx. Sp. Gr.
1800	Tan	Moh's 3	2.5	18.6	—	1.70
1900	Tan	Moh's 4	2.5	16.7	—	1.74
2000	Light brown	Moh's 5	2.5	10.7	—	1.93
2100	Brown	Moh's 6	12.5	0.3	—	2.32
2200	—	—	Expanded	—	—	—
2300						

Pyrometric cone equivalent: NA **Bloating test:** Positive

Remarks: Poor color; short vitrification range.

Bloating Tests (Quick-Firing):

Crushing characteristics: Angular — Particle size: —¾″ + ½″
Drying characteristics NA — Retention time: 15 minutes

Temp. °F	*Bulk Density*	*Lb/Ft³*	*% Absorb.*	*Remarks*
1800				
1900	2.25	140	4.5	No bloating
2000	1.04	65	7.7	Fair bloating; laminar
2100	0.79	49	9.5	Very good pore structure
2200				
2300				

Recommendations: Trial run in rotary kiln should be made.

ROTARY KILN TESTS:

Raw Material:

Screen Analysis (Crushed through a hammermill with 1½″ screen)

Size		*Percent Retained*
—¾″	+ ½″	29.1
—½″	+ ⅜″	16.8
—⅜″	+ 4 mesh	31.2
—4 mesh	+ 8 mesh	15.6
—8 mesh	PAN	7.3
	TOTAL	100.0

Crushing loss (—4 mesh) 22.9%

Fragment shape: Thin plates

Firing Data:

Size range of feed: —¾ + 4 mesh — Pour weight of feed: 92.6 lb/ft³

Bloating temperature: 2070°F

Logging temperature* (*Nodules sticking together): 2100°F

Fired Material (all fired material crushed through a roll crusher)

Screen Analysis* (*ASTM Designation C 311-59T) in percentages by weight passing sieves:

Size designation	¾″	½″	⅜″	No. 4	No. 8	No. 16	No. 50	No. 100
Fine	—	—	100.0	53.5	—	8.5	3.3	2.5
Coarse	100.0	91,2	78.4	41.0	11.5	—	—	—

Loose pour weight* (*ASTM Designation C 311-59T):

Fine: 58.8 lb/ft³ Coarse: 60.0 lb/ft³

Color: Tan

COMMENTS: Failed to meet ASTM weight specifications for coarse aggregate; undesirable fragment shape of fired product (thin plates); mostly thin plates. Laminar expansion; poor crushing.

Other Tests: Not effervescent in HCl.

Potential Uses: No designated ceramic use. Preliminary bloating tests indicate this material might be used for lightweight aggregate. Rotary kiln tests indicate that it is unsuitable for lightweight aggregate use.

LEHIGH COUNTY Weisenberg Twp.

Sample Number
196-7-4

Quadrangle: Albertis 15′, Topton 7½′

Location: Outcrop 0.5 mile southwest of Haffsville, Pa., on the south side of U. S. Route 22, and west of the William Penn Highway intersection.

Geologic Unit Martinsburg Formation, Ordovician

Description: Medium dark gray (N4) phyllitic shale is exposed in an outcrop about 1000 feet long and 25 feet high, with numerous covered intervals. In the eastern portion of the exposure, the shale is fresh to moderately weathered and light gray (N8) in color. The fresh shale is well indurated but, as the degree of weathering increases westward along the outcrop, the shale becomes progressively softer.

Attitude of Bedding: Horizontal. Cleavage: N75W, shallow dip.

Sampled Interval: Composite sample of exposed areas of the outcrop.

Type of Material: Shale

Ceramic Testing Laboratory: Tuscaloosa

Chemical Analysis:

Analyst: Conwell	%
L.O.I. @ 1,000°C	5.72
H_2O Loss @ 110°C	0.61
Combined H_2O	4.39
SiO_2	61.26
Al_2O_3	16.87
Fe_2O_3	1.40
FeO	3.89
CaO	1.21
MgO	3.27
CO_2	0.87
Na_2O	1.01
K_2O	3.36
TiO_2	0.77
P_2O_5	NA
MnO	NA
S (total)	0.67
C (total)	0.75

Mineralogy (X-ray):

	%	*Accuracy (±%)*
Quartz	30	5
Mica	30	8
Kaolinite	22	8
C-V-Mo	12	3
Feldspar	1	1

Remarks:

Other Properties:

pH: 7.20
P.C.E.: NA
Water of Plasticity (%): 22.5
Drying Shrinkage (%): 2.5
Dry Strength: Low
Drying Characteristics: No defects
Workability: Low plasticity

Slow-Firing Tests:

Temp. °F	*Color*	*Hardness*	*% Shk.*	*% Absorb.*	*% App. Por.*	*Approx. Sp. Gr.*
1800	Tan	Moh's 2	2.5	15.8	29.2	1.85
1900	Tan	Moh's 2	2.5	14.6	27.2	1.86
2000	Brown	Moh's 3	2.5	9.6	19.6	2.04
2100	Dark brown	Moh's 4	5.0	1.9	3.5	1.86
2200	—	—	Expanded	—	—	—
2300						

Pyrometric cone equivalent: NA **Bloating test:** Negative

Cone color: —

Remarks: Abrupt vitrification; may be limy.

Bloating Tests (Quick-Firing): NA

Other Tests: Slightly effervescent with HCl.

Potential Uses: No designated ceramic use.

MONROE COUNTY Eldred Twp.

Sample Number
205-4-9

Quadrangle: Wind Gap 15′; Kunkletown 7½′

Location: An abandoned clay pit 0.6 mile south-southwest of Kunkletown, Pa. The pit is reached by proceeding west for 0.3 mile on the Chestnut Ridge road leading off the north-south road between Smith Gap and Kunkletown, Pa.

Geologic Unit: Top of the Ridgeley Formation and base of the Bowmanstown Formation, Devonian.

Description: The sampled interval includes a thin zone of iron-rich sandstone and medium yellowish-brown (10 YR 5/2), semi-plastic clay-shale which weathers to a very light gray (N8) and mottled grayish-orange (10 YR 7/4). This material is limited to the western portion of the quarry.

The quarry is approximately 1600 feet long and 30 feet high. Sampling was started at the western end of the quarry and continued eastward for 400 feet along the north wall. The sampled interval has an estimated maximum stratigraphic thickness of 100 feet and a minimum thickness of 50 feet.

Attitude of Bedding: Steeply dipping to the south.

Sampled Interval: Composite sample of the western 400 feet of the north quarry wall.

Type of Material: Clay Shale

Ceramic Testing Laboratory: Tuscaloosa

Chemical Analysis:

Analyst: Conwell	%
L.O.I. @ 1,000°C	4.07
H_2O Loss @ 110°C	0.45
Combined H_2O	3.95
SiO_2	65.92
Al_2O_3	18.58
Fe_2O_3	2.19
FeO	0.58
CaO	0.10
MgO	1.17
CO_2	0.39
Na_2O	0.27
K_2O	5.66
TiO_2	0.93
P_2O_5	NA
MnO	NA
S (total)	None
C (total)	0.03

Mineralogy (X-ray):

	%	*Accuracy* (±%)
Quartz	37	5
Mica	35	6
Kaolinite	21	7
C-V-Mo	0	—
Feldspar	2	1

Remarks: Mineralogy indicates chemical analysis is high in K_2O.

Other Properties:

pH: 5.70
P.C.E.: NA
Water of Plasticity (%): 22.5
Drying Shrinkage (%): 0.0
Dry Strength: Low
Drying Characteristics: No defects
Workability: Low plasticity

Slow-Firing Tests:

Temp. °F	Color	Hardness	% Shk.	% Absorb.	% App. Por.	Approx. Sp. Gr.
1800	Ivory	Moh's 2	0.0	19.7	33.5	1.70
1900	Tan	Moh's 2	2.5	14.9	27.1	1.82
2000	Tan	Moh's 3	5.0	13.3	25.0	1.88
2100	Brown	Moh's 4	7.5	4.0	8.6	2.16
2200	Gray-brown	Moh's 5	10.0	1.5	3.4	2.24
2300	Gray	Moh's 6	10.0	0.1	0.2	2.24

Pyrometric cone equivalent: NA **Bloating test:** Negative

Bloating Tests (Quick-Firing): NA

Other Tests: Not effervescent with HCl.

Potential Uses: Should fire to "SW" face brick specifications at about 2050°F.

MONROE COUNTY Ross Twp.

Sample Number
205-5-3

Quadrangle: Wind Gap 15′; Wind Gap 7½′

Location: Property owned by the Universal Atlas Cement Division, U. S. Steel Corporation, about 4.1 miles east-northeast of Kunkletown, Pa.

Geologic Unit: New Scotland Formation, Devonian.

Description: White plastic clay, in part siliceous, is exposed in a trench excavated normal to the strike of bedding. The exposed clay measures about 12 feet in width and dips almost vertically. The clay is considered to be a weathered residuum of the New Scotland limestone. It has been tentatively suggested that water associated with glacial action was in part responsible for the leaching of the limestone.

Attitude of Bedding: Not measurable; vertical dip

Sampled Interval: Channel sample through six stratigraphic feet.

Type of Material: Residual clay

Ceramic Testing Laboratory: Norris

Chemical Analysis:

Analyst: Spectrochemical %

L.O.I. @ 1,000°C	3.74
H_2O Loss @ 110°C	0.20
Combined H_2O	NA
SiO_2	77.40
Al_2O_3	12.30
Fe_2O_3	0.94
FeO	ND
CaO	0.06

Mineralogy (X-ray):

	%	Accuracy (±%)
Quartz	49	6
Mica	33	8
Kaolinite	10	7
C-V-Mo	0	—
Feldspar	2	1

Remarks:

Chemical Analysis:

Analyst: Spectrochemical %

MgO	0.75
CO_2	0.13
Na_2O	0.30
K_2O	3.63
TiO_2	0.85
P_2O_5	NA
MnO	NA
S (total)	> 0.03
C (total)	0.09

Other Properties:

pH: 4.82
P.C.E.: 23-24
Water of Plasticity (%): 27.1
Drying Shrinkage (%): 0.5
Dry Strength: Fair
Drying Characteristics: Good; slight scum
Workability: Mealy; smooth; short-working

Slow-Firing Tests:

Temp. °F	*Color*	*Hardness*	*% Shk.*	*% Absorb.*	*% App. Por.*	*Approx. Sp. Gr.*
1800	Pink-white	Soft	1.0	4.2	—	1.95
1900	Pink-white	Fair hard	1.0	3.9	—	2.02
2000	Pink-white	Fair hard	2.0	4.3	—	2.02
2100	Pale gray	Hard	5.0	5.3	—	2.03
2200	Light gray	Very hard	9.0	8.1	—	1.99
2300	Light gray	Very hard	9.0	13.1	—	1.94

Pyrometric cone equivalent: 23-24 **Bloating test:** Negative
Cone color: Grey

Remarks: Very light color; shrinkage and absorption probably too high about 2400°F for low duty refractories; needs addition of alkali.

Bloating Tests (Quick-Firing): NA

Other Tests: Soluble Br. K. 0.50.

Potential Uses: Stoneware if alkali is added. Doubtful flue tile or low-duty refractory.

MONROE COUNTY Ross Twp.

Sample Number
205-5-4

Quadrangle: Wind Gap 15′, Kunkletown 7½′

Location: Quarry of Universal Atlas Cement Division of U. S. Steel Corporation on the south flank of Chestnut Ridge, about 3.5 miles east-northeast of Kunkletown, Pa.

Geologic Unit: Buttermilk Falls Limestone, Devonian.

Description: White plastic clay, in part siliceous, is exposed in the quarry. The clay is believed to have resulted from the leaching of the carbonate of the impure Buttermilk Falls limestone. The width of the quarry working face is about 100 feet.

Attitude of Bedding: Bedding not exposed in the quarry.

Sample Interval: Composite sample of the working face at east end of quarry.

Type of Material: Residual clay

Ceramic Testing Laboratory: Norris

Chemical Analysis:

Analyst: Spectrochemical %

L.O.I @ 1,000°C	3.22
H_2O Loss @ 110°C	0.16
Combined H_2O	NA
SiO_2	78.90
Al_2O_3	12.00
Fe_2O_3	0.70
FeO	ND
CaO	0.08
MgO	0.64
CO_2	0.15
Na_2O	0.21
K_2O	3.50
TiO_2	0.73
P_2O_5	NA
MnO	NA
S (total)	0.04
C (total)	0.14

Mineralogy (X-ray):

	%	Accuracy (±%)
Quartz	50	6
Mica	30	10
Kaolinite	14	7
C-V-Mo	0	
Feldspar	1	1

Remarks: Mineralogy indicates chemical analysis is low in Al_2O_3.

Other Properties:

pH: 5.05
P.C.E.: 24-25
Water of Plasticity (%): 27.9
Drying Shrinkage (%): 2.5
Dry Strength: Fair
Drying Characteristics: Good; slight scum
Workability: Mealy; smooth; short-working

Slow-Firing Tests:

Temp. °F	*Color*	*Hardness*	*% Shk.*	*% Absorb.*	*% App. Por.*	*Approx. Sp. Gr.*
1800	Pink-white	Soft	2.5	3.6	—	2.00
1900	Pink-white	Fair hard	2.5	3.6	—	2.03
2000	Pink-white	Fair hard	2.5	4.7	—	2.03
2100	Off white	Hard	5.0	5.6	—	1.98
2200	Pale gray	Very hard	7.5	10.7	—	1.93
2300	Light gray	Steel hard	9.0	19.1	—	1.91

Pyrometric cone equivalent: 24-25 **Bloating test:** Negative

Cone color: Gray

Remarks: Very light color; shrinkage and absorption probably too high about 2400°F for low-duty refractory brick. Needs addition of alkali.

Bloating Tests (Quick-Firing): NA

Other Tests: Soluble Br. K. 0.30.

Potential Uses: Stoneware if alkali is added. Doubtful flue tile or low-duty refractory.

Remarks: Presently being quarried for use in the manufacture of portland cement.

MONROE COUNTY Hamilton Twp.

Sample Number
205-6-8

Quadrangle: Wind Gap 15′; Saylorsburg 7½′

Location: New road cut on both sides of new U. S. Route 115 0.5 mile south of Saylorsburg, Pa. The site is south of an undesignated road between Saylorsburg and Bossardsville, Pa., which crosses over new U. S. Route 115.

Geologic Unit: Buttermilk Falls Limestone, Devonian.

Description: The entire Buttermilk Falls limestone residual clay unit was sampled. To the north the clay is in contact with the Marcellus shale and to the south with the Palmerton sandstone. The sample material is a tan to light-pinkish gray (5 YR 9/1), plastic clay containing visible chert and locally some limonite. The amount of chert in the clay increases toward the Palmerton sandstone contact. A zone of plastic, kaolinitic (?) shale probably six feet thick is found near the contact with the Marcellus shale. The northern 80 feet (including a 30 foot covered interval) of the exposure was sampled on the west side of U. S. Route 115; the remaining 295 feet of exposure was sampled on the east side of the road.

Attitude of Bedding: Palmerton sandstone: N85E, 52S.

Sampled Interval: Composite sample; material collected every 4 feet along the exposure.

Type of Material: Residual clay.

Ceramic Testing Laboratory: Tuscaloosa

Chemical Analysis:

Analyst: Conwell	%
L.O.I. @ 1,000°C	1.65
H_2O Loss @ 110°C	0.14
Combined H_2O	1.51
SiO_2	87.13
Al_2O_3	7.02
Fe_2O_3	0.88
FeO	0.07
CaO	0.15
MgO	0.01
CO_2	0.21
Na_2O	0.08
K_2O	1.71
TiO_2	0.34
P_2O_5	NA
MnO	NA
S (total)	None
C (total)	0.09

Mineralogy (X-ray):

	%	Accuracy (±%)
Quartz	64	8
Mica	20	8
Kaolinite	10	7
C-V-Mo	0	—
Feldspar	1	1

Remarks:

Other Properties:

pH: 6.40
P.C.E.: NA
Water of Plasticity (%): 23.6
Drying Shrinkage (%): 0.0
Dry Strength: Low
Drying Characteristics: No defects
Workability: Low plasticity

Slow-Firing Tests:

Temp. °F	*Color*	*Hardness*	*% Shk.*	*% Absorb.*	*% App. Por.*	*Approx. Sp. Gr.*
1800	Light gray	Moh's 2	0.0	23.8	37.1	1.56
1900	Light gray	Moh's 2	0.0	24.0	37.2	1.55
2000	Light gray	Moh's 2	0.0	23.3	36.8	1.58
2100	Gray	Moh's 2	2.5	20.2	33.3	1.65
2200	Gray	Moh's 3	2.5	15.5	27.0	1.74
2300	Gray	Moh's 4	2.5	12.6	22.2	1.76

Pyrometric cone equivalent: NA **Bloating test:** Negative

Remarks: Might also be suitable for glazed structural tile.

Bloating Tests (Quick-Firing): NA

Other Tests: Not effervescent with HCl.

Potential Uses: Flue liner.

MONTGOMERY COUNTY Pottsgrove Twp.

Sample Number
198-2-2

Quadrangle: Phoenixville 15′; Phoenixville 7½′

Location: The sample was collected at the Pottstown Trap Rock Quarry, Santoga Station Quarry, 0.8 mile south of Santoga, Pa.

Geologic Unit: Lockatong and Brunswick lithologies, Triassic.

Description: A sequence of green-gray shale-argillite and red mudstone-argillite, representing 50 stratigraphic feet, was sampled in the quarry as Samples 198-2-2A, 198-2-2B, and 198-2-2C; alloquet portions were combined to make composite Sample 198-2-2. The quarry was sampled by starting at the top of the quarry near the northwest corner (Sample 198-2-2A and youngest rock) and progressing through older beds around to the south wall and quarry floor (Sample 198-2-2C and oldest rock). The quarry is 50 feet deep, 600 feet long and 400 wide. A diabase dike, 15 to 20 feet wide and striking nearly N20E with vertical dip, has intruded the red shale in the quarry. A zone of contact metamorphism surrounds the dike for 10 feet on either side. Good quartz and calcite crystals, and stilbite are found in and around the dike and veinlets.

Attitude of Bedding: N70E, 14N. Attitude of Dike: N20E, Vertical

Sampled Interval: Composite sample of 50 stratigraphic feet.

Type of Material: Shale, argillite, mudstone

Ceramic Testing Laboratory: Tuscaloosa

Chemical Analysis:

Analyst: Conwell	%
L.O.I. @ 1,000°C	5.63
H_2O Loss @ 110°C	0.06
Combined H_2O	2.94
SiO_2	57.62
Al_2O_3	16.69
Fe_2O_3	1.77
FeO	4.03
CaO	4.23
MgO	2.88
CO_2	3.22
Na_2O	2.70
K_2O	2.54
TiO_2	0.80
P_2O_5	NA
MnO	NA
S (total)	0.17
C (total)	0.39

Mineralogy (X-ray):

	%	*Accuracy (±%)*
Quartz	23	5
Mica	32	6
Kaolinite	15	7
C-V-Mo	8	3
Feldspar	11	3

Remarks: Carbonate present.

Other Properties:

pH: 9.40
P.C.E.: NA
Water of Plasticity (%): 15.0
Drying Shrinkage (%): 0.0
Dry Strength: Low
Drying Characteristics: No defects
Workability: Low plasticity

Slow-Firing Tests:

Temp. °F	*Color*	*Hardness*	*% Shk.*	*% Absorb.*	*% App. Por.*	*Approx. Sp. Gr.*
1800	Tan	No bond	—	—	—	—
1900	Tan	No bond	—	—	—	—
2000	Light brown	Poor bond	—	—	—	—
2100	—	—	Expanded	—	—	—
2200						
2300						

Pyrometric cone equivalent: NA **Bloating test:** Negative

Remarks: No ceramic bond; may be limy. Not suitable for use as a principle component in vitreous clay products.

Bloating Tests (Quick-Firing): NA

Other Tests: Highly effervescent with HCl.

Potential Uses: No designated ceramic use.

MONTGOMERY COUNTY Pottsgrove Twp.

Sample Number
198-2-2A

Quadrangle: Phoenixville 15′; Phoenixville 7½′

Location: The sample was collected at the Pottstown Trap Rock Quarry, Inc., Santoga Station Quarry, located 0.8 mile south of Santoga, Pa.

Geologic Unit: Lockatong lithology, Triassic.

Description: This sample is one of three collected from this locality, and represents the top 20 stratigraphic feet of the wall-rock near the northwest corner of the quarry. The rock is dark gray and green-gray shale and argillite in beds ranging from less than ½ inch to more than 2 feet in thickness. In plan view the 50 foot-deep quarry is U-shaped with a vertical diabase dike oriented N20°E through the quarry. The east and west quarry walls are 400 feet long; the south wall is 600 feet long.

Attitude of Bedding: N70E, 14N

Sampled Interval: Composite sample of the top (youngest) 20 stratigraphic feet of the quarry.

Type of Material: Shale and argillite

Ceramic Testing Laboratory: Tuscaloosa

Chemical Analysis:

Analyst: Conwell	%
L.O.I. @ 1,000°C	7.06
H_2O Loss @ 110°C	0.06
Combined H_2O	2.59
SiO_2	57.04
Al_2O_3	15.29
Fe_2O_3	1.36
FeO	3.74
CaO	5.85
MgO	2.72

Mineralogy (X-ray):

	%	*Accuracy (±%)*
Quartz	29	5
Mica	23	6
Kaolinite	11	7
C-V-Mo	10	3
Feldspar	8	2

Remarks: Carbonate present.

Chemical Analysis:

Analyst: Conwell	%
CO_2	5.36
Na_2O	3.13
K_2O	2.50
TiO_2	0.82
P_2O_5	NA
MnO	NA
S (total)	0.05
C (total)	0.07

Other Properties:

pH: 9.40
P.C.E.: NA
Water of Plasticity (%): 15.1
Drying Shrinkage (%): 2.5
Dry Strength: Low
Drying Characteristics: No defects
Workability: Low plasticity

Slow-Firing Tests:

Temp. °F	*Color*	*Hardness*	*% Shk.*	*% Absorb.*	*% App. Por.*	*Approx. Sp. Gr.*
1800	Tan	Moh's 2	2.5	17.1	31.1	1.82
1900	Tan	Moh's 2	2.5	17.0	30.6	1.80
2000	Light brown	Moh's 3	2.5	15.1	27.5	1.82
2100	Brown	Moh's 4	2.5	1.1	2.0	1.86
2200	—	—	Expanded	—	—	—
2300						

Pyrometric cone equivalent: NA **Bloating test:** Negative

Remarks: Abrupt vitrification; may be limy.

Bloating Tests (Quick-Firing): NA

Other Tests: Highly effervescent with HCl.

Potential Uses: No designated ceramic use.

Remarks: See Sample 198-2-2 for more detailed description of the sampling site.

MONTGOMERY COUNTY Pottsgrove Twp.

Sample Number
198-2-2B

Quadrangle: Phoenixville 15′; Phoenixville 7½′

Location: Sample was collected from the Pottstown Trap Rock Quarry, Inc., Sanatoga Station Quarry, located 0.8 mile south of Sanatoga, Pa.

Geologic Unit: Lockatong Lithology, Triassic.

Description: This sample represents 16 stratigraphic feet immediately beneath Sample 198-2-2A and is continuation of sampling sequence along the west wall of the quarry. The sampled rock is dark gray and green-gray shale and argillite at the base of which is red mudstone and argillite sequence. The beds are very thin to massive and range from less than one inch to more than two feet in thickness.

Attitude of Bedding: N70E, 14N

Sampled Interval: Composite sample of 16 stratigraphic feet.

Type of Material: Shale and argillite

Ceramic Testing Laboratory: Tuscaloosa

Chemical Analysis:

Analyst: Conwell	%
L.O.I. @ 1,000°C	6.77
H_2O Loss @ 110°C	0.09
Combined H_2O	2.71
SiO_2	56.44
Al_2O_3	17.21
Fe_2O_3	0.58
FeO	4.25
CaO	5.04
MgO	2.57
CO_2	4.16
Na_2O	2.32
K_2O	3.44
TiO_2	0.73
P_2O_5	NA
MnO	NA
S (total)	0.08
C (total)	0.05

Mineralogy (X-ray):

	%	*Accuracy* (±%)
Quartz	29	6
Mica	31	8
Kaolinite	10	7
C-V-Mo	7	3
Feldspar	13	2

Remarks: Carbonate present.

Other Properties:

pH: 9.40
P.C.E.: NA
Water of Plasticity (%): 13.9
Drying Shrinkage (%): 2.5
Dry Strength: Low
Drying Characteristics: No defects
Workability: Low plasticity

Slow-Firing Tests:

Temp. °F	*Color*	*Hardness*	*% Shk.*	*% Absorb.*	*% App. Por.*	*Approx. Sp. Gr.*
1800	Tan	Moh's 2	2.5	17.5	31.5	1.80
1900	Tan	Moh's 2	2.5	17.8	31.9	1.79
2000	Light brown	Moh's 3	2.5	14.8	27.4	1.85
2100	Brown	Moh's 4	7.5	1.0	2.2	2.15
2200	—	—	Expanded	—	—	—
2300						

Pyrometric cone equivalent: NA **Bloating test:** Positive

Remarks: Not suitable for use in vitreous clay products; abrupt vitrification; may be limy.

Bloating Tests (Quick-Firing):

Crushing characteristics: Angular Particle size: ¾″ lumps
Drying characteristics: NA Retention time: 15 minutes

Temp. °F	*Bulk Density*	*Lb/Ft³*	*% Absorb.*	*Remarks*
1800	—	—	—	
1900	2.01	125.4	8.1	No expansion
2000	0.65	40.6	4.9	Fair expansion
2100	0.45	28.1	24.2	Overfired; vitreous
2200				
2300				

Recommendations: Marginal raw material for lightweight aggregate (short firing range).

Other Tests: Highly effervescent with HCl.

Potential Uses: Rotary kiln testing for lightweight aggregate use is suggested.

Remarks: See Sample 198-2-2 for more detailed description of the sample site.

MONTGOMERY COUNTY Pottsgrove Twp.

Sample Number
198-2-2C

Quadrangle: Phoenixville 15′; Phoenixville 7½′

Location: The sample was collected from the Pottstown Trap Rock Quarry, Inc., Sanatoga Station Quarry, located south of Sanatoga, Pa.

Geologic Unit: Brunswick lithology, Triassic.

Description: This sample represents 14 stratigraphic feet of section collected from the west and south walls of the quarry. This rock is the oldest rock in the quarry and consists of massive-beds of red mudstone and argillite.

Attitude of Bedding: N70E, 14N

Sampled Interval: Composite sample 14 stratigraphic feet oldest rocks in 3 sample sequence.

Type of Material: Mudstone and argillite.

Ceramic Testing Laboratory: Tuscaloosa

Chemical Analysis:

Analyst: Conwell	%
L.O.I. @ 1,000°C	5.99
H_2O Loss @ 110°C	0.21
Combined H_2O	2.79
SiO_2	56.48
Al_2O_3	16.58
Fe_2O_3	4.20
FeO	2.66
CaO	3.43
MgO	2.81
CO_2	3.40
Na_2O	3.44
K_2O	2.32
TiO_2	0.85
P_2O_5	NA
MnO	NA
S (total)	None
C (total)	0.10

Mineralogy (X-ray):

	%	Accuracy (±%)
Quartz	24	6
Mica	44	7
Kaolinite	5	3
C-V-Mo	6	3
Feldspar	5	2

Remarks: Carbonate present.

Other Properties:

pH: 9.40
P.C..E: NA
Water of Plasticity (%): 13.0
Drying Shrinkage (%): 2.5
Dry Strength: Low
Drying Characteristics: No defects
Workability: Low plasticity

Slow-Firing Tests:

Temp. °F	*Color*	*Hardness*	*% Shk.*	*% Absorb.*	*% App. Por.*	*Approx. Sp. Gr.*
1800	Light brown	Moh's 2	2.5	13.9	26.4	1.90
1900	Light brown	Moh's 2	2.5	15.4	28.2	1.84
2000	Brown	Moh's 3	2.5	12.5	23.4	1.87
2100	Red-brown	Moh's 4	5.0	2.3	4.6	2.01
2200	—	—	Expanded	—	—	—
2300						

Pyrometric cone equivalent: NA **Bloating test:** Positive

Remarks: Not suitable for use in vitreous clay products. Abrupt vitrification; may be limy.

Bloating Tests (Quick-Firing):

Crushing characteristics: Angular Particle size: ¾″ lumps
Drying characteristics: NA Retention time: 15 minutes

Temp. °F	*Bulk Density*	*Lb/Ft³*	*% Absorb.*	*Remarks*
1800	—	—	—	
1900	2.22	138.5	4.4	No expansion
2000	0.67	41.8	8.4	Good expansion
2100	0.48	30.0	20.1	Overfired
2200	—	—	—	
2300	—	—	—	

Recommendations: Promising material for lightweight aggregate.

Other Tests: Highly effervescent with HCl.

Potential Uses: Quick firing tests indicate this to be promising material for lightweight aggregate.

Remarks: See Sample 198-2-2 for more detailed description of the sampling site.

MONTGOMERY COUNTY Salford Twp.

Sample Number
207-5-3

Quadrangle: Quakertown 15′; Perkiomenville 7½′

Location: Road cut along the west side of the Northeast Extension of the Pennsylvania Turnpike about 1.3 miles south of the Bucks-Montgomery County line.

Geologic Unit: Lockatong Formation, Triassic.

Description: Dark gray to grayish black, thin to massive-bedded, dense argillite is exposed for 1000 feet along the Pennsylvania Turnpike. Bedding in the predominant, more massive, argillite is 6 inches to 5 feet thick. The thinner argillite beds are only about two inches thick. Slightly weathered argillite is tough and breaks with a conchoidal fracture. Fragments along the base of the exposure are irregular in shape and have sharp edges. Analcime (?) is widely scattered throughout the rock and disseminated pyrite is a minor constituent in some of the beds. The height of the exposure is 25 feet.

Attitude of Bedding: N80E, 8N

Sampled Interval: A composite sample of 30 stratigraphic feet was collected, starting at the Clump Road overpass and continuing south along the Turnpike outcrop.

Type of Material: Argillite

Ceramic Testing Laboratory: Tuscaloosa

Chemical Analysis:

Analyst: Conwell	%
L.O.I. @ 1,000°C	1.08
H_2O Loss @ 110°C	0.08
Combined H_2O	1.27
SiO_2	52.98
Al_2O_3	19.89
Fe_2O_3	1.90

Mineralogy (X-ray):

	%	*Accuracy (±%)*
Quartz	10	8
Mica	59	6
Kaolinite	0	—
C-V-Mo	0	—
Feldspar	21	4
Remarks:		

Chemical Analysis:

Analyst: Conwell

	%
FeO	6.70
CaO	2.67
MgO	4.20
CO_2	0.04
Na_2O	4.54
K_2O	4.42
TiO_2	0.75
P_2O_5	NA
MnO	NA
S (total)	None
C (total)	0.15

Other Properties:

pH: 7.30
P.C.E.: NA
Water of Plasticity (%): 18.7
Drying Shrinkage (%): 0.0
Dry Strength: Low
Drying Characteristics: No drying defects
Workability: Low plasticity

Slow-Firing Tests:

Temp. °F	*Color*	*Hardness*	*% Shk.*	*% Absorb.*	*% App. Por.*	*Approx. Sp. Gr.*
1800	Light brown	Moh's 2	0.0	17.5		1.75
1900	Light brown	Moh's 2	0.0	17.0		1.76
2000	Brown	Moh's 3	0.0	0.7		2.38
2100	Melted	—	—	—		—
2200						
2300						

Pyrometric cone equivalent: NA **Bloating test:** Negative

Remarks: Poor color; short vitrification range.

Bloating Tests (Quick-Firing): NA

Other Tests: Slightly effervescent with HCl.

Potential Uses: No designated ceramic use.

MONTGOMERY COUNTY Perkiomen Twp.

Sample Number
207-7-2A

Quadrangle: Quakertown 15′; Perkiomenville 7½′

Location: Outcrop exposure between Pa. Route 29 and Perkiomen Creek, south of Haldeman Road and the south boundary of Schwenksville, Pa.

Geologic Unit: Lockatong Formation, Triassic.

Description: Predominantly massive, interbedded, olive gray to medium-dark gray argillite and brownish red siltstone, including 30 inches of greenish gray, thin-bedded shale, are exposed for 18 stratigraphic feet. Some of the argillite beds are calcareous. The base of the sample interval is about 25 feet south of the C.G.&E. pole #495 S-PK.

Attitude of Bedding: N75E, 20N

Sampled Interval: Composite sample of 18 stratigraphic feet.

Type of Material: Argillite, siltstone and shale.

Ceramic Testing Laboratory: Norris

Chemical Analysis:

Analyst: McCreath	%
L.O.I. @ 1,000°C	NA
H_2O Loss @ 110°C	NA
Combined H_2O	3.95
SiO_2	53.42
Al_2O_3	15.27
Fe_2O_3	5.76
FeO	1.47
CaO	4.10
MgO	3.68
CO_2	4.57
Na_2O	4.07
K_2O	3.34
TiO_2	0.87
P_2O_5	NA
MnO	NA
S (total)	< 0.03
C (total)	0.08

Mineralogy (X-ray):

	%	Accuracy (±%)
Quartz	19	5
Mica	39	6
Kaolinite	10	6
C-V-Mo	10	3
Feldspar	12	3

Remarks: Carbonate present.

Other Properties:

pH: 9.20
P.C.E.: NA
Water of Plasticity (%): 23.0
Drying Shrinkage (%): 4.0
Dry Strength: Fair
Drying Characteristics: Poor; warping, scum, rough
Workability: Short-working; smooth, fatty

Slow-Firing Tests:

Temp. °F	*Color*	*Hardness*	*% Shk.*	*% Absorb.*	*% App. Por.*	*Approx. Sp. Gr.*
1800	Light tan	Fair hard	4.5	4.4	—	2.69
1900	Light tan	Fair hard	4.5	4.5	—	2.67
2000	Light tan	Hard	6.0	4.9	—	2.62
2100	Melted	—	—	—	—	—
2200						
2300						

Pyrometric cone equivalent: NA **Bloating test:** Positive

Remarks: Fair color, warped, scum, slightly rough, soft.

Bloating Tests (Quick-Firing):

Crushing characteristics. Good Particle size: —¾″ + ½″
Drying characteristics: Good Retention time: 15 minutes

Temp. °F	*Bulk Density*	*Lb/Ft³*	*% Absorb.*	*Remarks*
1800	—	—	—	
1900	2.45	153	1.7	No expansion
2000	2.14	134	1.7	Slight expansion
2100	1.19	75	2.9	Fair expansion, good skin
2200				Melted
2300				

Recommendations: Fair lightweight aggregate.

ROTARY KILN TESTS:

Raw Material:

Screen Analysis (Crushed through a hammermill with 1½" screen)

Size		Percent Retained
—¾"	+ ½"	31.4
—½"	+ ⅜"	14.1
—⅜"	+ 4 mesh	18.4
—4 mesh	+ 8 mesh	5.2
—8 mesh	PAN	30.9
	TOTAL	100.0

Crushing loss (—4 mesh) 36.1%

Fragment shape: Angular and platy

Firing Data:

Size range of feed: —¾ + 4 mesh Pour weight of feed: 88.0 lb/ft^3

Bloating temperature: 1970°F

Logging temperature* (*Nodules sticking together): 1990°F

Fired Material (all fired material crushed through a roll crusher)

Screen Analysis* (*ASTM Designation C 311-59T) in percentages by weight passing sieves:

Size designation	¾"	½"	⅜"	No. 4	No. 8	No. 16	No. 50	No. 100
Fine	—	—	100.0	60.0	—	27.0	13.1	9.4
Coarse	100.0	63.0	39.0	13.0	8.8	—	—	—

Loose pour weight* (*ASTM Designation C 311-59T):

Fine: 67.5 lb/ft^3 Coarse: 60.0 lb/ft^3

COMMENTS: Not promising for lightweight aggregate; too heavy; angular fragments; mostly non-bloating material; color: tan to brown.

Other Tests: Soluble Br. K. 0.91

Potential Uses: Rotary kiln tests indicate this material is not promising for lightweight aggregate production.

Remarks: See also Sample 207-7-2B.

MONTGOMERY COUNTY Perkiomen Twp.

Sample Number
207-7-2B

Quadrangle: Quakertown 15′; Perkiomenville 7½′

Location: Outcrop exposure between Pa. Route 29 and Perkiomen Creek, south of Kaldeman Road and the south boundary of Schwenksville, Pa.

Geologic Unit: Lockatong Formation, Triassic

Description: Gray-red to very dark red, medium- to massive-bedded shale is exposed for a stratigraphic interval of 35 feet, starting about 20 feet south of C.G.& E. pole #50-3N. The beds vary from 1 to 5 feet in thickness.

Attitude of Bedding: N75E, 20N

Sampled Interval: Composite sample of 35 stratigraphic feet.

Type of Material: Shale

Ceramic Testing Laboratory: Norris

Chemical Analysis:

Analyst: McCreath

	%
L.O.I. @ 1,000°C	NA
H_2O Loss @ 110°C	NA
Combined H_2O	3.43
SiO_2	52.23
Al_2O_3	16.85
Fe_2O_3	7.78
FeO	0.22
CaO	2.51
MgO	3.50
CO_2	2.90
Na_2O	4.91
K_2O	4.53
TiO_2	0.90
P_2O_5	NA
MnO	NA
S (total)	$>$ 0.01
C (total)	0.07

Mineralogy (X-ray):

	%	Accuracy (±%)
Quartz	15	5
Mica	52	6
Kaolinite	13	7
C-V-Mo	0	
Feldspar	10	2

Remarks:

Other Properties:

pH: 9.30
P.C.E.: NA
Water of Plasticity (%): 23.0
Dry Shrinkage (%): 5.0
Dry Strength: Good
Drying Characteristics: Fair; slightly wavy, scum
Workability: Short-working, smooth, fatty

Slow-Firing Tests:

Temp. °F	Color	Hardness	% Shk.	% Absorb.	% App. Por.	Approx. Sp. Gr.
1800	Light red brown	Fair hard	5.5	5.9	—	2.61
1900	Light red brown	Hard	5.5	5.6	—	2.59
2000	Light brown	Very hard	5.5	8.1	—	2.50
2100	Melted	—	—	—	—	—
2200						
2300						

Pyrometric cone equivalent: NA **Bloating test:** Positive

Remarks: Fair color, warping, scum. Addition of barium salts would improve. Short range firing.

Bloating Tests (Quick-Firing):

Crushing characteristics: Good Particle size: —¾″ + ½″
Drying characteristics: Good Retention time: 15 minutes

Temp. °F	Bulk Density	Lb/Ft³	% Absorb.	Remarks
1800	—	—	—	
1900	2.50	156	1.7	No expansion
2000	1.90	124	1.9	Slight expansion
2100	1.49	93	2.6	Fair expansion—good skin
2200	—	—	—	Melted
2300				

Recommendations: A little heavy for lightweight aggregate possibility.

Other Tests: Soluble Br. K. 1.00

Potential Uses: Face brick

Remarks: See Sample also 207-7-2A

MONTGOMERY COUNTY Perkiomenville Twp.

Sample Number
207-8-4

Quadrangle: Quakertown 15′; Perkiomenville 7½′

Location: Exposure along the west side of the Northeast Extension of the Pennsylvania Turnpike located about 200 feet south of the Creamery Road underpass.

Geologic Unit: Brunswick Formation, Triassic

Description: Grayish red, medium-bedded, slightly weathered shales and silty shales are exposed for a distance of 750 feet along the Pennsylvania Turnpike. The beds are 6 inches to 2 feet thick. Rock Fragments are predominantly irregular to tabular in shape and average several inches in length. Beds at the north end of the exposure exhibit closely spaced parting planes on joint surfaces. The maximum height of the exposure is 25 feet.

Attitude of Bedding: N85W, 14N

Sampled Interval: Composite samples of 35 stratigraphic feet.

Type of Material: Shale and silty shale

Ceramic Testing Laboratory: Tuscaloosa

Chemical Analysis:

Analyst: Conwell	%
L.O.I. @ 1,000°C	5.06
H_2O Loss @ 110°C	0.55
Combined H_2O	2.64
SiO_2	52.86
Al_2O_3	18.28
Fe_2O_3	7.95
FeO	0.86
CaO	2.82
MgO	2.86
CO_2	2.62
Na_2O	4.11
K_2O	3.36
TiO_2	0.83
P_2O_5	NA
MnO	NA
S (total)	None
C (total)	0.19

Mineralogy (X-ray):

	%	Accuracy (±%)
Quartz	16	5
Mica	45	6
Kaolinite	5	4
C-V-Mo	7	3
Feldspar	17	3

Remarks: Carbonate present.

Other Properties:

pH: 7.40
P.C.E.: NA
Water of Plasticity (%): 20.0
Drying Shrinkage (%): 0.0
Dry Strength: Low
Drying characteristics: No drying defects
Workability: Low plasticity

Slow-Firing Tests:

Temp. °F	Color	Hardness	% Shk.	% Absorb.	% App. Por.	Approx. Sp. Gr.
1800	Red tan	Moh's 3	0.0	18.2	—	1.73
1900	Red tan	Moh's 3	0.0	17.9	—	1.73
2000	Light brown	Moh's 4	0.0	12.8	—	1.84
2100	Melted	—	—	—	—	—
2200						
2300						

Pyrometric cone equivalent: NA **Bloating test:** Negative

Remarks: Poor color; short vitrification range.

Bloating Tests (Quick-Firing): NA

Other Tests: Highly effervescent in HCl.

Potential Uses: No designated ceramic use.

MONTGOMERY COUNTY Towamencin Twp.

Sample Number
208-2-3

Quadrangle: Norristown 15′; Lansdale 7½′

Location: Road cut along the west side of the Northeast Extension of the Pennsylvania Turnpike about 1.3 miles south of the Lansdale, Pa., exit.

Geologic Unit: Brunswick Formation, Triassic.

Description: Grayish red, thin- to massive-bedded shale is exposed for 1000 feet along the west side of the Pa. Turnpike. The beds range from several inches to three feet in thickness. Locally the shale is slightly to moderately calcareous with hair-line veinlets of calcite parallel to some joints. The shale is only slighty weathered and some of the more massive beds show finely laminated structures (due to weathering) on joint planes. Fragments of the shale are commonly irregular to tabular and range from an inch to several inches in length. The height of the exposure is 15 feet.

Attitude of Bedding: N50-65E, 6-10N

Sampled Interval: Composite sample of 200 feet in the extreme southern portion of the outcrop.

Type of Material: Shale

Ceramic Testing Laboratory: Tuscaloosa

Chemical Analysis:

Analyst: Conwell	%
L.O.I. @ 1,000°C	5.22
H_2O Loss @ 110°C	0.22
Combined H_2O	2.86
SiO_2	62.06
Al_2O_3	15.74
Fe_2O_3	2.77
FeO	3.16
CaO	2.82
MgO	1.73
CO_2	1.94
Na_2O	1.65
K_2O	2.26
TiO_2	0.78
P_2O_5	NA
MnO	NA
S (total)	None
C (total)	0.11

Mineralogy (X-ray):

	%	Accuracy (±%)
Quartz	35	5
Mica	38	6
Kaolinite	6	4
C-V-Mo	7	3
Feldspar	4	2
Remarks:		

Other Properties:

pH: 7.30
P.C.E.: NA
Water of Plasticity (%): 19.6
Drying Shrinkage (%): 0.0
Dry Strength: Low
Drying Characteristics: No drying defects
Workability: Low plasticity

Slow-Firing Tests:

Temp. °F	Color	Hardness	% Shk.	% Absorb.	% App. Por.	Approx. Sp. Gr.
1800	Red tan	Moh's 3	0.0	18.2	—	1.75
1900	Red tan	Moh's 3	0.0	16.9	—	1.77
2000	Light brown	Moh's 4	0.0	13.5	—	1.86
2100	Dark brown	Moh's 6	10.0	0.9	—	2.06
2200	—	—	Expanded	—	—	—
2300						

Pyrometric cone equivalent: NA **Bloating test:** Negative

Remarks: Poor color; short vitrification range.

Bloating Tests (Quick-Firing): NA

Other Tests: Highly effervescent in HCl.

Potential Uses: No designated ceramic use.

MONTGOMERY COUNTY Worchester Twp.

Sample Number

208-3-4

Quadrangle: Norristown 15′, Lansdale 7½′

Location: Road cut on the west side of the Northeast Extension of the Pennsylvania Turnpike, about 0.4 mile north of the Reading Railroad underpass west of Belfry Station, Pa.

Geologic Unit: Lockatong Formation, Triassic.

Description: Medium-dark to dark-gray, interbedded shale and argillite are exposed for 1000 feet along the west side of the Pennsylvania Turnpike. The shale beds are fissile to thin-bedded but the argillite beds, in contrast, are several feet thick. Some argillite beds contain thin layers of calcareous material which weathers to a tan color. Pyrite occurs in some of the dark gray shale beds. Shale fragments are platy to fissile; the argillite fragments are irregular to tabular. Bedding and fracture surfaces are normally limonite stained. The height of the exposure is 15 feet.

Attitude of Bedding: N45E, 14N

Sampled Interval: Composite sample of 15 stratigraphic feet collected from the southern end of the outcrop.

Type of Material: Shale and argillite

Ceramic Testing Laboratory: Tuscaloosa

Chemical Analysis:

Analyst: Conwell	%
L.O.I. @ 1,000°C	6.73
H_2O Loss @ 110°C	0.47
Combined H_2O	3.98
SiO_2	50.00
Al_2O_3	18.22
Fe_2O_3	4.81

Mineralogy (X-ray):

	%	Accuracy (±%)
Quartz	13	5
Mica	54	6
Kaolinite	4	3
C-V-Mo	8	3
Feldspar	16	3

Remarks: Carbonate present.

Chemical Analysis:

Analyst: Conwell	%
FeO	3.16
CaO	3.63
MgO	3.43
CO_2	3.06
Na_2O	3.67
K_2O	4.13
TiO_2	0.72
P_2O_5	NA
MnO	NA
S (total)	None
C (total)	0.29

Other Properties:

pH: 7.40
P.C.E.: NA
Water of Plasticity (%): 20.00
Drying Shrinkage (%): 0.0
Dry Strength: Low
Drying Characteristics: No drying defects
Workability: Low plasticity

Slow-Firing Tests:

Temp. °F	Color	Hardness	% Shk.	% Absorb.	% App. Por.	Approx. Sp. Gr.
1800	Tan	Moh's 3	2.5	21.4	—	1.61
1900	Tan	Moh's 4	2.5	12.6	—	1.78
2000	Brown	Moh's 5	2.5	5.2	—	1.98
2100	—	—	Expanded	—	—	—
2200						
2300						

Pyrometric cone equivalent: NA **Bloating test:** Negative

Remarks: Poor color; short vitrification range.

Bloating Tests (Quick-Firing): NA

Other Tests: Highly effervescent with HCl.

Potential Uses: No designated ceramic use.

MONTGOMERY COUNTY Lower Providence Twp.

Sample Number
208-5-2A

Quadrangle: Norristown 15′; Collegeville 7½′

Location: Quarry on the north side of the road between Trooper and Audubon, Pa., 1.8 miles northeast of Audubon, Pa.

Geologic Unit: Lockatong Formation, Triassic.

Description: Medium gray, slightly calcareous, fissile shale has a massive character along the jointing, especially in the upper part of the sample interval. The shale is slightly weathered, and iron oxide stains are common along fractures. The shale fragments are platy and rather small. The sampling unit represents nine stratigraphic feet of section and was collected at the west end of the quarry. The quarry is 100 feet long and 28 feet high.

Attitude of Bedding: Variable strike from N60W to N90E; dipping gently to the N and NE.

Sampled Interval: Composite of 9 stratigraphic feet.

Type of Material: Shale

Ceramic Testing Laboratory: Norris

Chemical Analysis:

Analyst: McCreath

	%
L.O.I. @ 1,000°C	NA
H_2O Loss @ 110°C	NA
Combined H_2O	5.76
SiO_2	50.16
Al_2O_3	17.17
Fe_2O_3	8.15
FeO	0.78
CaO	2.27
MgO	4.20
CO_2	2.02
Na_2O	4.89
K_2O	3.72
TiO_2	0.90
P_2O_5	NA
MnO	NA
S (total)	< 0.01
C (total)	0.07

Mineralogy (X-ray):

	%	Accuracy (±%)
Quartz	14	6
Mica	55	7
Kaolinite	5	4
C-V-Mo	9	3
Feldspar	6	2

Remarks:

Other Properties:

pH: 9.15
P.C.E.: NA
Water of Plasticity (%): 22.0
Drying Shrinkage (%): 5.0
Dry Strength: Good
Drying Characteristics: Good, slight scum
Workability: Short-working, smooth, fatty

Slow-Firing Tests:

Temp. °F	*Color*	*Hardness*	*% Shk.*	*% Absorb.*	*% App. Por.*	*Approx. Sp. Gr.*
1800	Red tan	Fair hard	5.5	5.6	—	2.64
1900	Red tan	Hard	6.5	5.7	—	2.60
2000	Light brown	Very hard	9.5	12.8	—	2.55
2100	Melted	—	—	—	—	—
2200						
2300						

Pyrometric cone equivalent: NA **Bloating test:** Positive

Remarks: Poor color, addition of barium salts might improve. Color needs improving.

Bloating Tests (Quick-Firing):

Crushing characteristics: Good Particle size: —¾″ + ½″
Drying characteristics: Good Retention time: 15 minutes

Temp. °F	*Bulk Density*	*Lb/Ft³*	*% Absorb.*	*Remarks*
1800	2.69	168	1.8	No expansion
1900	2.40	150	4.0	Very slight expansion
2000	1.21	75	5.0	Fair expansion—layered cracks
2100	—	—	—	Melted
2200				
2300				

Recommendations: Fair lightweight aggregate possibility; short bloating range.

ROTARY KILN TESTS:

Raw Material:

Screen Analysis (Crushed through a hammermill with 1½" screen)

Size		Percent Retained
—¾"	+ ½"	12.9
—½"	+ ⅜"	11.9
—⅜"	+ 4 mesh	33.5
—4 mesh	+ 8 mesh	13.2
—8 mesh	PAN	28.5
	TOTAL	100.0

Crushing loss (—4 mesh) 41.7%

Fragment shape: Thin plates

Firing Data:

Size range of feed: —¾ + 4 mesh Pour weight of feed: 90.0 lb/ft³

Bloating temperature: 2030°F

Logging temperature* (*Nodules sticking together): 2040°F

Fired Material (all fired material crushed through a roll crusher)

Screen Analysis* (*ASTM Designation C 311-59T) in percentages by weight passing sieves:

Size designation	¾"	½"	⅜"	No. 4	No. 8	No. 16	No. 50	No. 100
Fine	—	—	100.0	66.0	—	24.0	8.2	5.4
Coarse	100.0	82.0	54.0	10.0	3.8	—	—	—

Loose pour weight* (*ASTM Designation C 311-59T):

Fine: 57.5 lb/ft³ Coarse: 52.5 lb/ft³

COMMENTS: Not promising for lightweight aggregate; short firing range; angular and flat plates: good crushing; fair pore structure; mixture of bloating and non-bloating materials. NOTE: This is a composite sample of Samples 208-5-2A, B, and C.

Other Tests: Soluble Br. K. 1.00

Potential Uses: Face brick, if color improved. Rotary kiln testing of a composite of Samples 208-5-2A, B and C indicates this material has no potential for lightweight aggregate. However, quick-firing tests of Sample 208-5-2A indicate it might produce a fair lightweight aggregate.

Remarks: See also Samples 208-5-2B and 208-5-2C. Samples 208-5-2A, 208-5-2B, and 208-5-2C collected as one sample for rotary kiln tests.

MONTGOMERY COUNTY Lower Providence Twp.

Sample Number

208-5-2B

Quadrangle: Norristown 15′; Collegeville 7½′

Location: Quarry on the north side of the road between Trooper and Audubon, Pa., 1.8 miles northeast of Audubon, Pa.

Geologic Unit: Lockatong Formation, Triassic.

Description: Dark gray, slightly calcareous, fissile shale represents three stratigraphic feet of section immediately below Sample 208-5-2A. The shale is slightly weathered and iron stains are common along fractures. Lithologically this sample is similar to Sample 208-5-2A but is darker in color.

Attitude of Bedding: Variable strike from N60W to N90E; dipping to the N and NE.

Sampled Interval: Composite of three stratigraphic feet.

Type of Material: Shale

Ceramic Testing Laboratory: Norris

Chemical Analysis:

Analyst: Conwell	%
L.O.I. @ 1,000°C	8.38
H_2O Loss @ 110°C	0.77
Combined H_2O	4.58
SiO_2	50.36
Al_2O_3	16.22
Fe_2O_3	3.84
FeO	3.02
CaO	5.64
MgO	3.93
CO_2	2.83
Na_2O	3.24
K_2O	2.14
TiO_2	0.62
P_2O_5	NA
MnO	NA
S (total)	None
C (total)	0.95

Mineralogy (X-ray):

	%	Accuracy (±%)
Quartz	21	7
Mica	37	8
Kaolinite	7	5
C-V-Mo	12	3
Feldspar	13	3

Remarks:

Other Properties:

pH: 9.10
P.C.E.: NA
Water of Plasticity (%): 22.0
Drying Shrinkage (%): 5.5
Dry Strength: Good
Drying Characteristics: Good, slightly wavey
Workability: Short-working, smooth, fatty

Slow-Firing Tests:

Temp. °F	Color	Hardness	% Shk.	% Absorb.	% App. Por.	Approx. Sp. Gr.
1800	Reddish tan	Fair hard	5.5	5.0	—	2.65
1900	Reddish tan	Fair hard	5.5	4.6	—	2.60
2000	Tan	Hard	5.5	7.9	—	2.58
2100	Melted	—	—	—	—	—
2200						
2300						

Pyrometric cone equivalent: NA **Bloating test:** Positive

Remarks: Fair color, slightly wavy, soft.

Bloating Tests (Quick-Firing):

Crushing characteristics: Fair, shaly
Drying characteristics: Good
Particle size: —¾″ + ½″
Retention time: 15 minutes

Temp. °F	Bulk Density	Lb/Ft³	% Absorb.	Remarks
1800	2.65	165	1.1	No expansion
1900	2.50	156	4.2	Very slight expansion
2000	0.98	61	10.0	Good expansion, poor skin
2100	—	—	—	Melted
2200				
2300				

Recommendations: Good lightweight aggregate possibility.

Other Tests: Soluble Br. K. 0.99

Potential Uses: Rotary kiln testing of a composite of Samples 208-5-2A, B, and C indicate material is not promising for lightweight aggregate use. However, quick-firing tests of Sample 208-5-2B indicate the raw material has good lightweight aggregate possibility.

Remarks: See Samples 208-5-2A and 208-5-2C. Samples 208-5-2A, 208-5-2B, and 208-5-2C collected as one sample for rotary kiln tests. See Sample 208-5-2A for results of rotary kiln testing.

MONTGOMERY COUNTY Lower Providence Twp.

Sample Number
208-5-2C

Quadrangle: Norristown 15′, Collegeville 7½′

Location: Quarry on the north side of the road connecting Trooper and Audubon, Pa., 1.8 miles northeast of Audubon, Pa.

Geologic Unit: Lockatong Formation, Triassic.

Description: Blackish- to very dusky-red, thin-bedded to fissile, slightly calcareous shale represents a stratigraphic interval of 5 feet immediately underlying Sample 208-5-2B. The beds range from less than 0.1 inch to 1 inch in thickness.

Attitude of Bedding: Variable strike from N60W to N90E; dipping gently to the N and NE.

Sampled Interval: Composite of five stratigraphic feet.

Type of Material: Shale

Ceramic Testing Laboratory: Norris

Chemical Analysis:

Analyst: Conwell	%
L.O.I. @ 1,000°C	8.24
H_2O Loss @ 110°C	0.46
Combined H_2O	4.94
SiO_2	47.77
Al_2O_3	19.87
Fe_2O_3	4.72
FeO	2.30
CaO	3.98
MgO	4.52
CO_2	3.74
Na_2O	2.32
K_2O	4.13
TiO_2	0.67
P_2O_5	NA
MnO	NA
S (total)	None
C (total)	0.08

Mineralogy (X-ray):

	%	*Accuracy* (±%)
Quartz	9	5
Mica	64	6
Kaolinite	12	7
C-V-Mo	0	
Feldspar	5	2

Remarks:

Other Properties:

pH: 9.40
P.C.E.: NA
Water of Plasticity (%): 22.0
Drying Shrinkage (%): 5.0
Dry Strength: Good
Drying Characteristics: Good, slight checking
Workability: Short-working, smooth, fatty

Slow-Firing Tests:

Temp. °F	Color	Hardness	% Shk.	% Absorb.	% App. Por.	Approx. Sp. Gr.
1800	Light brown	Fair hard	5.5	6.0	—	2.61
1900	Light brown	Fair hard	5.5	6.2	—	2.59
2000	Brown	Hard	6.0	7.1	—	2.47
2100	Melted	—	—	—	—	—
2200						
2300						

Pyrometric cone equivalent: NA **Bloating test:** Positive

Remarks: Fair color, slightly wavy, melted about 2025°F, soft.

Bloating Tests (Quick-Firing):

Crushing characteristics: Good Particle size: —¾" + ½"
Drying characteristics: Good Retention time: 15 minutes

Temp. °F	Bulk Density	Lb/Ft³	% Absorb.	Remarks
1800	2.43	152	3.1	Very slight expansion
1900	2.21	140	4.0	Slight expansion
2000	1.32	82	9.0	Fair expansion, poor skin
2100	—	—	—	Melted
2200				
2300				

Recommendations: Fair lightweight aggregate possibility—probably too short bloating range.

Other Tests: Soluble Br. K. 1.00

Potential Uses: Rotary kiln testing of a composite of Samples 208-5-2A, B, and C indicates material is not promising for lightweight aggregate use. However, quick-firing tests of Sample 208-5-2C indicate it has fair lightweight aggregate potential.

Remarks: See Samples 208-5-2A and 208-5-2B. Samples 208-5-2A, 208-5-2B, and 208-5-2C collected as one sample for rotary kiln tests. See Sample 208-5-2A for results of rotary kiln testing.

MONTGOMERY COUNTY Montgomery Twp.

Sample Number

218-1-1A

Quadrangle: Germantown 15′; Ambler 7½′

Location: Gill Quarry north of the intersection of Hartman Road and U. S. Route 309, about 1.4 miles southeast of Montgomery Square, Pa.

Geologic Unit: Lockatong Formation, Triassic.

Description: Predominantly medium- to thick-bedded, medium- to dark-gray argillite is exposed in the quarry walls. The more highly weathered beds in the upper part of the quarry walls are dark-greenish- to olive-gray and range in thickness from three inches to three feet in thickness. Some beds are slightly calcareous and weather to a tan color. Rust colored to yellow-brown or yellow-orange staining is common along fractures. The argillite contains a minor amount of analcime (?) and pyrite. The quarry is 300 by 600 feet in plan and 50 feet high. The soil overburden ranges from 5 to 10 feet thick. The sample was collected in the upper part of the southeast corner of the quarry.

Attitude of Bedding: N50E, 7N

Sampled Interval: Composite sample of 15 stratigraphic feet of section.

Type of Material: Argillite

Ceramic Testing Laboratory: Tuscaloosa

Chemical Analysis:

Analyst: Conwell	%
L.O.I. @ 1,000°C*	6.21
H_2O Loss @ 110°C	0.60
Combined H_2O	3.44
SiO_2	49.68
Al_2O_3	18.95
Fe_2O_3	4.15
FeO	3.74
CaO	3.50
MgO	3.29
CO_2	2.87
Na_2O	4.40
K_2O	3.88
TiO_2	0.83
P_2O_5	0.21
MnO	0.12
S (total)	0.03
C (total)	0.60

* Nitrogen atmosphere

Mineralogy (X-ray):

	%	Accuracy (±%)
Quartz	13	5
Mica	58	6
Kaolinite	4	2
C-V-Mo	8	3
Feldspar	12	3

Remarks:

Other Properties:

pH: 8.20
P.C.E.: NA
Water of Platicity (%): 22.2
Drying Shrinkage (%): 0.0
Dry Strength: Low
Drying Characteristics: No drying defects
Workability: Low plasticity

Slow-Firing Tests:

Temp. °F	*Color*	*Hardness*	*% Shk.*	*% Absorb.*	*% App. Por.*	*Approx. Sp. Gr.*
1800	Tan	Moh's 1	0.0	22.5	—	1.64
1900	Tan	Moh's 4	0.0	23.8	—	1.61
2000	Brown	Moh's 5	2.5	12.5	—	1.83
2100	—	—	expanded	—	—	—
2200	—	—	—	—	—	—
2300						

Pyrometric cone equivalent: NA **Bloating test:** Negative

Remarks: Poor color; short vitrification range.

Bloating Tests (Quick-Firing): NA

Crushing characteristics: Angular Particle size: —¾″ + ½″
Drying characteristics: NA Retention time: 15 minutes

Temp. °F	*Bulk Density*	*Lb/Ft³*	*% Absorb.*	*Remarks*
1800	1.80	112	4.1	No bloating
1900	1.15	72	3.7	Slight bloating
2000	0.61	38	20.5	Melted
2100				
2200				
2300				

Recommendations: Firing range too short for rotary kiln processing.

Other Tests: Highly effervescent in HCl.

Semi-quantitative spectrographic analysis shows the following trace element abundance: Ba (>0.1%), Sr (>0.01 <0.1%), Zr, and V (>0.001 <0.01%). Other elements such as Zn, Cu, Cr, and Ni, if present, are less than 0.001%.

Potential Uses: No designated ceramic use.

Remarks: See Sample 218-1-1B.

MONTGOMERY COUNTY Montgomery Twp.

Sample Number
218-1-1B

Quadrangle: Germantown 15′; Ambler 7½′

Location: Gill Quarry north of the intersection of Hartman Road and Pa. Route 309, about 1.4 miles southeast of Montgomery Square, Pa.

Geologic Unit: Lockatong Formation, Triassic.

Description: Predominantly medium- to thick-bedded, medium- to dark-gray argillite is exposed in the quarry walls. The more intensely weathered beds in the upper part of the quarry walls are dark-greenish- to olive-gray and range in thickness from 3 inches to 3 feet. Some beds are slightly calcareous and weather to a tan color. Rust colored to yellow-brown or yellow-orange staining is common along fractures. The argillite contains minor amounts of analcime and pyrite. The quarry is 300 by 600 feet in plan and 50 feet high. The soil overburden ranges from 5 to 10 feet thick. The sample was collected in the upper part of the southeast corner of the quarry. Sample 218-1-1B represents a composite sample of 15 stratigraphic feet of rock underlying Sample 218-1-1A.

Attitude of Bedding: N50E, 7N

Sampled Interval: Composite sample of 15 stratigraphic feet.

Type of Material: Argillite

Ceramic Testing Laboratory: Tuscaloosa

Chemical Analysis:

Analyst: Conwell	%
L.O.I. @ 1,000°C*	11.24
H_2O Loss @ 110°C	0.52
Combined H_2O	3.32
SiO_2	44.02
Al_2O_3	16.66
Fe_2O_3	1.84
FeO	4.96
CaO	7.21
MgO	4.29
CO_2	8.24
Na_2O	4.20
K_2O	3.42
TiO_2	0.68
P_2O_5	0.16
MnO	0.14
S (total)	0.08
C (total)	0.81

* Nitrogen atmosphere

Mineralogy (X-ray):

	%	*Accuracy (±%)*
Quartz	10	4
Mica	47	6
Kaolinite	6	3
C-V-Mo	6	3
Feldspar	16	3

Remarks: Carbonate present.

Other Properties:

pH: 7.40
P.C.E.: NA
Water of Plasticity (%): 19.7
Drying Shrinkage (%): 0.0
Dry Strength: Low
Drying Characteristcs: No drying defects
Workability: Low plasticity

Slow-Firing Tests:

Temp. °F	Color	Hardness	% Shk.	% Absorb.	% App. Por.	Approx. Sp. Gr.
1800	Beige	Moh's 1	0.0	42.6	—	1.25
1900	Beige	Moh's 1	0.0	28.8	—	1.48
2000	Brown	Moh's 3	5.0	11.9	—	1.66
2100	—	—	Expanded	—	—	—
2200						
2300						

Pyrometric cone equivalent: NA **Bloating test:** Positive

Remarks: Poor color; short vitrification range.

Bloating Tests (Quick-Firing):

Crushing characteristics: Angular Particle size: —¾″ + ½″
Drying characteristics: NA Retention time: 15 minutes

Temp. °F	Bulk Density	Lb/Ft³	% Absorb.	Remarks
1800				
1900	1.77	110	6.6	No bloating
2000	0.74	46	7.5	Good pore structure; vitreous skin
2100	0.63	39	15.5	Some large pores; thin walls
2200				
2300				

Recommendations: Trial run in rotary kiln should be made.

Other Tests: Highly effervescent in HCl.

Semi-quantitative spectrographic analysis shows the following trace element abundance: Ba (>0.1%), Sr (>0.01 <0.1%), Zr, V, and Pb (>0.001 <0.01%). Other elements such as Zn, Cu, Cr, and Ni, if present, are less than 0.001%.

Potential Uses: Lightweight aggregate, if rotary kiln tests suggest such use.

Remarks: See Sample 218-1-1A.

MONTGOMERY COUNTY Montgomery Twp.

Sample Number
218-1-2

Quadrangle: Germantown 15′; Ambler 7½′

Location: Montgomery Stone Company, Inc., quarry on the north side of Upper State Road, about 0.5 mile northeast of Montgomery Square, Pa.

Geologic Unit: Lockatong Formation, Triassic.

Description: Dark gray to grayish black, interbedded medium- to massive-bedded, well indurated argillite is exposed. Analcime (?) and pyrite are scattered throughout the rock. Mudcracks occur in some beds. The quarry is 450 x 650 feet in plan and 100 feet deep.

Attitude of Bedding: N45-50E, 10N

Sampled Interval: Composite sample representing 15 stratigraphic feet collected from the upper working bench at the northeast corner of the quarry.

Type of Material: Argillite

Ceramic Testing Laboratory: Tuscaloosa

Chemical Analysis:

Analyst: Conwell	%
L.O.I. @ 1,000°C*	6.77
H_2O Loss @ 110°C	0.37
Combined H_2O	3.39
SiO_2	50.50
Al_2O_3	18.25
Fe_2O_3	2.38
FeO	5.25
CaO	4.12
MgO	3.01
CO_2	3.54
Na_2O	4.11
K_2O	4.20
TiO_2	0.78
P_2O_5	0.16
MnO	0.11
S (total)	0.03
C (total)	0.26

* Nitrogen atmosphere

Mineralogy (X-ray):

	%	*Accuracy (±%)*
Quartz	16	5
Mica	49	6
Kaolinite	10	6
C-V-Mo	8	3
Feldspar	12	2

Remarks:

Other Properties:

pH: 7.40
P.C.E.: NA
Water of Plasticity (%): 19.8
Drying Shrinkage (%): 0.0
Dry Strength: Low
Drying Characteristics: No drying defects
Workability: Low plasticity

Slow-Firing Tests:

Temp. °F	*Color*	*Hardness*	*% Shk.*	*% Absorb.*	*% App. Por.*	*Approx. Sp. Gr.*
1800	Beige	1	0.0	24.3	—	1.57
1900	Beige	1	0.0	23.9	—	1.57
2000	Brown	4	2.5	16.4	—	1.69
2100	—	—	Expanded	—	—	—
2200						
2300						

Pyrometric cone equivalent: NA **Bloating test:** Negative

Remarks: Poor color; short vitrification range.

Bloating Tests (Quick-Firing):

Crushing characteristics: Angular Particle size: —¾" + ½"
Drying characteristics: NA Retention time: 15 minutes

Temp. °F	*Bulk Density*	*Lb/Ft³*	*% Absorb.*	*Remarks*
1800				
1900	—	—	—	Decrepitated in water
2000	0.97	60	5.2	
2100	0.74	46	7.2	
2200				
2300				

Recommendations: Not suitable for lightweight aggregate.

Other Tests: Highly effervescent in HCl.

Semi-quantitative spectrographic analysis shows the following trace element abundance: Ba (>0.1%), Sr, Zr, and V (>0.001 <0.01%). Other elements such as Zn, Cu, Cr, and Ni, if present, are less than 0.001%.

Potential Uses: No designated ceramic use.

NORTHAMPTON COUNTY Lehigh Twp.

Sample Number
195-9-4

Quadrangle: Mauch Chunk 15′; Palmerton 7½′

Location: Old Griffith Slate Quarry (abandoned) about 0.5 mile northeast of Apps, Pa., a few hundred feet north of the Lehigh and New England Railroad right-of-way.

Geologic Unit: Martinsburg Formation, Upper Soft Slate Member, Ordovician.

Description: Medium-gray slate was collected from the Old Griffith Quarry waste slate dump. The slate is reportedly of fair dimension-slate quality although it is moderately weathered and iron stained. The dimensions of the waste dump are approimately 50 x 50 x 100 feet. The quarry in plan view is a rectangular opening measuring 50 x 100 feet and filled with at least 20 feet of water.

Attitude of Bedding: N57E, 43S; beds are overturned. Attitude of cleavage: N60E, 75S.

Sampled Interval: Grab sample of slate from waste dump.

Type of Material: Slate

Ceramic Testing Laboratory: Tuscaloosa

Chemical Analysis:

Analyst: Conwell	%
L.O.I. @ 1,000°C	7.80
H_2O Loss @110°C	0.19
Combined H_2O	3.86
SiO_2	57.20
Al_2O_3	15.28
Fe_2O_3	2.55
FeO	4.10
CaO	4.84
MgO	2.61
CO_2	3.75
Na_2O	1.08
K_2O	2.40
TiO_2	0.70
P_2O_5	NA
MnO	NA
S (total)	0.61
C (total)	0.38

Mineralogy (X-ray):

	%	Accuracy (±%)
Quartz	29	5
Mica	29	6
Kaolinite	22	7
C-V-Mo	9	3
Feldspar	2	1

Remarks: Carbonate present.

Other Properties:

pH: 8.50
P.C.E.: NA
Water of Plasticity (%): 20.8
Drying Shrinkage (%): 2.5
Dry Strength: Low
Drying Characteristics: No drying defects
Workability: Low plasticity

Slow-Firing Tests:

Temp. °F	Color	Hardness	% Shk.	% Absorb.	% App. Por.	Approx. Sp. Gr.
1800	Beige	Moh's 3	2.5	20.0	—	1.67
1900	Beige	Moh's 4	2.5	19.8	—	1.68
2000	Beige	Moh's 5	2.5	18.2	—	1.73
2100	Brown	Moh's 6	10.0	1.6	—	2.05
2200	—	—	Expanded	—	—	—
2300						

Pyrometric cone equivalent: NA **Bloating test:** Positive

Remarks: Poor color; short vitrification range.

Bloating Tests (Quick-Firing):

Crushing characteristics: Angular Particle size: —¾" + ½"
Drying characteristics: NA Retention time: 15 minutes

Temp. °F	Bulk Density	Lb/Ft³	% Absorb.	Remarks
1800				
1900	2.36	147	3.1	No bloating
2000	1.52	95	9.5	Very little bloating
2100	0.82	51	10.0	Fair pore structure
2200				
2300				

Recommendations: Trial run in rotary kiln should be made.

Other Tests: Highly effervescent in HCl.

Potential Uses: Lightweight aggregate, if rotary kiln tests confirm Preliminary Bloating Tests.

NORTHAMPTON COUNTY Lehigh Twp.

Sample Number
195-9-5

Quadrangle: Mauch Chunk 15′, Palmerton 7½′

Location: Peters Quarries (abandoned) about 0.5 mile southwest of Berlinsville, Pa.

Geologic Unit: Martinsburg Formation, Upper Soft Slate Member, Ordovician.

Description: The sample was collected from a moderate-sized dump produced by the quarrying operations in the westernmost of two quarries in a group of openings southwest of Berlinsville, Pa. The sample consists of slightly to moderately weathered medium gray waste slate having a tinge of blue. The two quarries lie in a north-south line and are roughly circular in plan. Each quarry is about 200 feet in diameter and reportedly 80 feet deep.

Attitude of Bedding: N72E, 68S; beds overturned in north quarry. Antiformal axis passes through the south quarry. The attitude of the axial plane is approximately N60E, 50S.

Sampled Interval: Grab sample from slate dump.

Type of Material: Slate

Ceramic Testing Laboratory: Tuscaloosa

Chemical Analysis:

Analyst: Conwell	%
L.O.I. @ 1,000°C	7.17
H_2O Loss @ 110°C	0.27
Combined H_2O	4.33
SiO_2	57.66
Al_2O_3	16.23
Fe_2O_3	2.56
FeO	4.18
CaO	4.64
MgO	2.82
CO_2	2.99
Na_2O	1.08
K_2O	2.40
TiO_2	0.85
P_2O_5	NA
MnO	NA
S (total)	0.79
C (total)	0.17

Mineralogy (X-ray):

	%	Accuracy (±%)
Quartz	30	5
Mica	26	6
Kaolinite	20	7
C-V-Mo	10	3
Feldspar	3	2

Remarks: Carbonate present.

Other Properties:

pH: 8.40
P.C.E.: NA
Water of Plasticity (%): 19.1
Drying Shrinkage (%): 2.5
Dry Strength: Low
Drying Characteristics: No drying defects
Workability: Low plasticity

Slow-Firing Tests:

Temp. °F	Color	Hardness	% Shk.	% Absorb.	% App. Por.	Approx. Sp. Gr.
1800	Beige	Moh's 3	2.5	18.1	—	1.72
1900	Beige	Moh's 4	2.5	18.0	—	1.68
2000	Beige	Moh's 5	2.5	16.1	—	1.71
2100	Brown	Moh's 6	10.0	1.0	—	2.01
2200	—	—	Expanded	—	—	—
2300						

Pyrometric cone equivalent: NA **Bloating test:** Positive

Remarks: Poor color; short vitrification range.

Bloating Tests (Quick-Firing):

Crushing characteristics: NA Particle size —¾" + ½"
Drying characteristics: NA Retention time: 15 minutes

Temp. °F	Bulk Density	Lb/Ft³	% Absorb.	Remarks
1800				
1900	2.18	136	4.6	No bloating
2000	1.12	70	12.3	Slight bloating
2100	0.51	32	15.9	Good pore structure
2200				
2300				

Recommendations: Trial run in rotary kiln should be made.

Other Tests: Highly effervescent in HCl.

Potential Uses: Lightweight aggregate, if rotary kiln tests confirm Preliminary Bloating Tests.

NORTHAMPTON COUNTY Plainfield Twp.

Sample Number
205-6-7

Quadrangle: Wind Gap 15′; Wind Gap 7½′

Location: Abandoned slate quarry, called the Tinsman Quarry, 0.4 mile southwest of Wind Gap, Pa.

Geologic Unit: Martinsburg Formation, Upper Soft Slate Member, Ordovician.

Description: Slightly weathered, medium gray slate with a bluish tinge is exposed on the waste dumps adjacent to the quarry. In plan the quarry is roughly rectangular measuring 300 x 500 feet and is reported to be about 245 feet deep.

Attitude of Bedding: N73E to N75W, variable dip but average is 32 to 37S. The quarry has been opened on the lower limb of an antiform overturned to the north. Transverse folding has complicated the structure and accounts for the variable strike and dip of the beds.

Sampled Interval: Grab sample collected from the waste dump.

Type of Material: Shale

Ceramic Testing Laboratory: Tuscaloosa

Chemical Analysis:

Analyst: Conwell	%
L.O.I. @ 1,000°C	7.54
H_2O Loss @ 110°C	0.10
Combined H_2O	4.50
SiO_2	56.48
Al_2O_3	14.42
Fe_2O_3	2.70
FeO	3.96
CaO	4.31
MgO	2.93
CO_2	3.32
Na_2O	1.62
K_2O	4.47
TiO_2	0.82
P_2O_5	NA
MnO	NA
S (total)	0.65
C (total)	0.42

Mineralogy (X-ray):

	%	Accuracy (±%)
Quartz	23	6
Mica	35	8
Kaolinite	21	7
C-V-Mo	9	3
Feldspar	2	1

Remarks: Carbonate present.

Other Properties:

pH: 8.30
P.C.E.: NA
Water of Plasticity (%): 20.9
Drying Shrinkage (%): 0.0
Dry Strength: Low
Drying Characteristics: No drying defects
Workability: Low plasticity

Slow-Firing Tests:

Temp. °F	*Color*	*Hardness*	*% Shk.*	*% Absorb.*	*% App. Por.*	*Approx. Sp. Gr.*
1800	Beige	Moh's 2	0.0	21.6	—	1.61
1900	Beige	Moh's 3	0.0	20.6	—	1.62
2000	Beige	Moh's 4	0.0	19.9	—	1.65
2100	Brown	Moh's 6	0.0	3.0	—	1.73
2200	—	—	Expanded	—	—	—
2300						

Pyrometric cone equivalent: NA **Bloating test:** Positive

Remarks: Poor color; short vitrification range.

Bloating Test (Quick-Firing):

Crushing characteristics: Platy — Particle size: —¾" + ½"
Drying characteristics: NA — Retention time: 15 minutes

Temp. °F	*Bulk Density*	*Lb/Ft³*	*% Absorb.*	*Remarks*
1800				
1900	1.91	119	12.5	No bloating
2000	0.99	62	10.3	Fair pore structure, laminar
2100	0.50	31	18.1	Pore structure poor; thin walls
2200				
2300				

Recommendations: Trial run in rotary kiln should be made.

Other Tests: Highly effervescent in HCl.

Potential Uses: Lightweight aggregate if rotary kiln tests indicate it to be suitable raw material.

NORTHAMPTON COUNTY Moore Twp.

Sample Number
205-8-5

Quadrangle: Wind Gap 15′; Kunkletown 7½′

Location: Abandoned quarry sites (Chapman Quarry) just southeast of Chapman, Pa.

Geologic Unit: Martinsburg Formation, Lower Hard Slate Member, Ordovician.

Description: Slightly weathered, medium gray slate wtih a blue tinge is piled on waste slate dumps adjacent to the Chapman Quarry. Chapman Quarry consists of two openings, separated by a wall of rock 50 feet wide. The opening to the west in roughly rectangular and measures about 400 x 600 feet and is reported to be 130 feet deep. The eastern opening measures 400 feet x 1,000 feet and is 150 feet deep.

Attitude of Bedding: Western quarrying site: N60-70E, dips variable due to folding.

Sampled Interval: Grab sample from the dump at the western quarry.

Type of Material: Slate

Ceramic Testing Laboratory: Tuscaloosa

Chemical Analysis:

Analyst: Conwell	%
L.O.I. @ 1,000°C	6.15
H_2O Loss @ 110°C	0.10
Combined H_2O	3.30
SiO_2	60.02
Al_2O_3	14.61
Fe_2O_3	1.04
FeO	4.82
CaO	2.97

Mineralogy (X-ray):

	%	*Accuracy (±%)*
Quartz	35	8
Mica	20	10
Kaolinite	20	9
C-V-Mo	8	3
Feldspar	2	1

Remarks: Mineralogy indicates chemical analysis is high in K_2O, or mica content should be greater.

Chemical Analysis:

Analyst: Conwell

	%
MgO	3.24
CO_2	2.60
Na_2O	1.57
K_2O	4.54
TiO_2	0.85
P_2O_5	NA
MnO	NA
S (total)	0.57
C (total)	0.26

Other Properties:

pH: 8.40
P.C.E.: NA
Water of Plasticity (%): 20.8
Drying Shrinkage (%): 0.0
Dry Strength: Low
Drying Characteristics: No drying defects
Workability: Low plasticity

Slow-Firing Tests:

Temp. °F	*Color*	*Hardness*	*% Shk.*	*% Absorb.*	*% App. Por.*	*Approx. Sp. Gr.*
1800	Beige	Moh's 2	0.0	23.9	—	1.56
1900	Beige	Moh's 3	0.0	21.9	—	1.59
2000	Beige	Moh's 4	0.0	17.9	—	1.67
2100	—	—	Expanded	—	—	—
2200						
2300						

Pyrometric cone equivalent: NA **Bloating test:** Positive

Remarks: Poor color; short vitrification range.

Bloating Tests (Quick-Firing):

Crushing characteristics: Platy Particle size: —¾″ + ½″
Drying characteristics: NA Retention time: 15 minutes

Temp. °F	*Bulk Density*	*Lb/Ft³*	*% Absorb.*	*Remarks*
1800				
1900	1.66	103	7.3	No bloating
2000	0.86	54	9.9	Fair pore structure; laminar
2100	0.49	31	10.6	Poor pore structure; thin walls
2200				
2300				

Recommendations: Trial run in rotary kiln should be made.

ROTARY KILN TESTS:

Raw Material:

Screen Analysis (Crushed through a hammermill with 1½″ screen)

Size		*Percent Retained*
—¾″	+ ½″	25.1
—½″	+ ⅜″	10.9
—⅜″	+ 4 mesh	21.7
—4 mesh	+ 8 mesh	12.1
—8 mesh	PAN	30.2
	TOTAL	100.0

Crushing loss (—4 mesh) 42.3%

Fragment shape: Tabular

Firing Data:

Size range of feed: —¾ + 4 mesh   Pour weight of feed: 88.2 lb/ft³
Bloating temperature: 1990°F
Logging temperature* (*Nodules sticking together): 2030°F

Fired Material (all fired material crushed through a roll crusher)

Screen Analysis* (*ASTM Designation C 311-59T) in percentages by weight passing sieves:

Size designation	¾"	½"	⅜"	No. 4	No. 8	No. 16	No. 50	No. 100
Fine	—	—	100.0	69.5	—	22.3	7.6	4.8
Coarse	100.0	85.2	69.5	36.9	13.0	—	—	—

Loose pour weight* (*ASTM Designation C 311-59T):
Fine: 55.6 lb/ft³   Coarse: 52.5 lb/ft³

Color: Gray

COMMENTS: Excessive crushing loss of raw material; tabular lumps and thin plates; fair pore structure; poor crushing.

Other Tests: Highly effervescent in HCl.

Potential Uses: Rotary kiln tests indicate this material is not particularly suitable for lightweight aggregate manufacture, and would probably make only a fair quality lightweight aggregate at best.

NORTHAMPTON COUNTY Plainfield Twp.

Sample Number
205-9-6

Quadrangle: Wind Gap 15′; Wind Gap 7½′

Location: Abandoned slate quarry (Northampton Quarry) 0.3 mile east of Werkheiser, Pa. The quarry site is about 500 feet east of the Erie-Lackawanna Railroad tracks.

Geologic Unit: Martinsburg Formation, Lower Hard Slate Member, Ordovician.

Description: Slightly weathered, medium gray slate with a blue tinge is piled on waste slate dumps adjacent to the Northampton Quarry. The quarry is 250 x 450 feet in plan and is reported to be 350 feet deep.

Attitude of Bedding: N80E to N80W, dips are generally to the north but variable due to tight folding.

Sampled Interval: Grab sample from the waste slate dump.

Type of Material: Slate

Ceramic Testing Laboratory: Tuscaloosa

Chemical Analysis:

Analyst: Conwell	%
L.O.I. @ 1,000°C	5.85
H_2O Loss @ 110°C	0.38
Combined H_2O	3.82
SiO_2	61.00
Al_2O_3	14.07

Mineralogy (X-ray):

	%	*Accuracy (±%)*
Quartz	32	8
Mica	30	10
Kaolinite	16	10
C-V-Mo	10	3
Feldspar	2	1

Chemical Analysis:

Analyst: Conwell	%
Fe_2O_3	1.76
FeO	4.75
CaO	1.97
MgO	3.37
CO_2	0.77
Na_2O	1.46
K_2O	4.42
TiO_2	0.67
P_2O_5	NA
MnO	NA
S (total)	0.76
C (total)	0.58

Mineralogy (X-ray):

Remarks: Data uncertain—chemical analysis apparently slightly high in K_2O. Carbonate present.

Other Properties:

pH: 7.30
P.C.E.: NA
Water of Plasticity (%): 18.9
Drying Shrinkage (%): 0.0
Dry Strength: Low
Drying Characteristics: No drying defects
Workability: Low plasticity

Slow-Firing Tests:

Temp. °F	*Color*	*Hardness*	*% Shk.*	*% Absorb.*	*% App. Por.*	*Approx. Sp. Gr.*
1800	Beige	Moh's 2	0.0	23.5	—	1.54
1900	Beige	Moh's 2	0.0	19.1	—	1.63
2000	Light brown	Moh's 2	0.0	15.8	—	1.68
2100	—	—	Expanded	—	—	—
2200						
2300						

Pyrometric cone equivalent: NA **Bloating test:** Positive

Remarks: Poor color; short vitrification range.

Bloating Tests (Quick-Firing):

Crushing characteristics: Platy
Drying characteristics: NA
Particle size: —¾″ + ½″
Retention time: 15 minutes

Temp. °F	*Bulk Density*	*Lb/Ft³*	*% Absorb.*	*Remarks*
1800				
1900	1.79	112	8.4	No bloating
2000	0.91	57	12.3	Fair pore structure; laminar
2100	0.52	32	15.8	Fair pore structure; slight fusion
2200				
2300				

Recommendations: Trial run in rotary kiln should be made.

ROTARY KILN TESTS:

Raw Material:

Screen Analysis (Crushed through a hammermill with 1½″ screen)

Size		*Percent Retained*
—¾″	+ ½″	22.0
—½″	+ ⅜″	11.7
—⅜″	+ 4 mesh	27.8
—4 mesh	+ 8 mesh	19.6
—8 mesh	PAN	18.9
	TOTAL	100.0

Crushing loss (—4 mesh) 38.5%

Fragment shape: Thin plates

Firing Data:

Size range of feed: —¾ + 4 mesh Pour weight of feed: 81.6 lb/ft³
Bloating temperature: 2010°F
Logging temperature* (*Nodules sticking together): 2100°F

Fired Material (all fired material crushed through a roll crusher)
Screen Analysis* (*ASTM Designation C 311-59T) in percentages by weight passing sieves:

Size designation	¾"	½"	⅜"	No. 4	No. 8	No. 16	No. 50	No. 100
Fine	—	—	100.0	87.1	—	34.1	11.7	7.2
Coarse	100.0	91.9	75.7	39.7	12.1	—	—	—

Loose pour weight* (*ASTM Designation C 311-59T):
Fine: 53.8 lb/ft³ Coarse: 48.1 lb/ft³

Color: Light brown

COMMENTS: Undesirable fragment shape of fire product (thin plates); mostly thin plates; laminar expansion; poor crushing.

Other Tests: Highly effervescent in HCl.

Potential Uses: Rotary kiln tests indicate this material is not very suitable for lightweight aggregate use. It would probably make fair quality lightweight aggregate.

NORTHAMPTON COUNTY East Allen Twp.

Sample Number
206-1-1

Quadrangle: Allentown 15'; Catasauqua 7½'

Location: "Miller's Slate Pond," one mile southwest of Jamesville, Pa.

Geologic Unit: Martinsburg Formation, Ordovician.

Description: A sequence of light- and dark-banded, slightly weathered slate beds was sampled. The dark-banded slate splits into 1/16 to 2 inch thick beds which when fresh are dark gray (N4) and when weathered, medium gray (N5). The light-banded slate beds are 1/8 to 2 inches thick, weather to a medium light gray (N6), and break into rough, thin, platy fragments.

Attitude of Bedding: Not measured.

Sampled Interval: Grab sample of the light- and dark-banded slate from the quarry.

Type of Material: Slate

Ceramic Testing Laboratory: Tuscaloosa

Chemical Analysis:

Analyst: Conwell	%
L.O.I. @ 1,000°C	6.66
H_2O Loss @ 110°C	0.14
Combined H_2O	4.86
SiO_2	59.22
Al_2O_3	15.60

Mineralogy (X-ray):

	%	*Accuracy (±%)*
Quartz	28	5
Mica	23	6
Kaolinite	32	7
C-V-Mo	10	3
Feldspar	2	1

Chemical Analysis:

Analyst: Conwell	%
Fe_2O_3	1.98
FeO	4.18
CaO	2.62
MgO	3.33
CO_2	0.68
Na_2O	1.46
K_2O	4.42
TiO_2	0.68
P_2O_5	NA
MnO	NA
S (total)	0.72
C (total)	0.70

Mineralogy (X-ray):

Remarks: Mineralogy indicates chemical analysis is high in K_2O, or low in % mica.

Other Properties:

pH: 9.90
P.C.E.: NA
Water of Plasticity (%): 15.7
Drying Shrinkage (%): 0.0
Dry Strength: Low
Drying Characteristics: No defects
Workability: Low plasticity

Slow-Firing Tests:

Temp. °F	*Color*	*Hardness*	*% Shk.*	*% Absorb.*	*% App. Por.*	*Approx. Sp. Gr.*
1800	Tan	Moh's 2	0.0	22.1	36.7	1.66
1900	Tan	Moh's 2	0.0	21.8	36.0	1.65
2000	Light brown	Moh's 3	0.0	19.7	33.1	1.68
2100	—	—	Expanded	—	—	—
2200						
2300						

Pyrometric cone equivalent: NA **Bloating test:** Negative

Remarks: Abrupt vitrification; may be limy.

Bloating Tests (Quick-Firing): NA

Other Tests: Highly effervescent with HCl.

Potential Uses: No designated ceramic use.

NORTHAMPTON COUNTY Moore Twp.

Sample Number
206-1-2

Quadrangle: Allentown 15′, Catasauqua 7½′

Location: Exposure on the northeast side of Pa. Route 248 (U.S.G.S. Topographic Quadranlge maps indicate this as Pa. Route 45) approximately 0.2 mile southeast of Reersville, Pa.

Geologic Unit: Martinsburg Formation, Ordovician.

Description: Pale-yellowish brown (10 YR 6/2), slaty shale that weathers to a light gray (N7) is exposed in a roadcut, 40 feet long and 12 feet high. The laminae of the shale range from 1/16 to 1/2 inch in thickness.

Attitude of Bedding: Bedding is essentially horizontal, but sample site is part of a monoclinal fold.

Sampled Interval: Composite of the outcrop.

Type of Material: Slaty shale

Ceramic Testing Laboratory: Tuscaloosa

Chemical Analysis:

Analyst: Conwell	%
L.O.I. @ 1,000°C	4.08
H_2O Loss @ 110°C	0.05
Combined H_2O	3.60
SiO_2	64.08
Al_2O_3	15.68
Fe_2O_3	3.20
FeO	3.46
CaO	0.55
MgO	2.92
CO_2	1.32
Na_2O	0.86
K_2O	3.46
TiO_2	0.72
P_2O_5	NA
MnO	NA
S (total)	0.04
C (total)	0.35

Mineralogy (X-ray):

	%	Accuracy (±%)
Quartz	36	6
Mica	27	8
Kaolinite	21	7
C-V-Mo	9	3
Feldspar	2	1

Remarks: Carbonate present.

Other Properties:

pH: 9.70
P.C.E.: NA
Water of Plasticity (%): 18.5
Drying Shrinkage (%): 0.0
Dry Strength: Low
Drying Characteristics: No defects
Workability: Low Plasticity

Slow-Firing Tests:

Temp. °F	*Color*	*Hardness*	*% Shk.*	*% Absorb.*	*% App. Por.*	*Approx. Sp. Gr.*
1800	Light brown	Moh's 2	0.0	20.2	34.3	1.70
1900	Light brown	Moh's 2	2.5	19.0	33.1	1.74
2000	Brown	Moh's 3	2.5	13.8	26.1	1.89
2100	Red-brown	Moh's 5	5.0	1.9	4.0	2.11
2200	—	—	Expanded	—	—	—
2300						

Pyrometric cone equivalent: NA **Bloating test:** Negative

Remarks: Abrupt vitrification; may be limy.

Bloating Tests (Quick-Firing): NA

Other Tests: Highly effervescent with HCl.

Potential Uses: No designated ceramic use.

NORTHAMPTON COUNTY Upper Mount Bethel Twp.

Sample Number
215-2-3

Quadrangle: Delaware Water Gap 15′; Portland 7½′

Location: Outcrop in the northwest quadrant of the intersection of Slateford Creek and alternate U. S. Route 611 in Slateford, Pa.

Geologic Unit: Martinsburg Formation, Ordovician.

Description: Medium-dark gray (N4), moderately to highly weathered slate that weathers to a light gray (N7) and is exposed in outcrop.

Attitude of Bedding: Not measured

Sampled Interval: Composite sample of outcrop.

Type of Material: Slate

Ceramic Testing Laboratory: Tuscaloosa

Chemical Analysis:

Analyst: Conwell	%
L.O.I. @ 1,000°C	5.37
H_2O Loss @ 110°C	0.61
Combined H_2O	3.74
SiO_2	60.94
Al_2O_3	15.64
Fe_2O_3	6.00
FeO	1.30
CaO	1.16
MgO	2.68
CO_2	0.96
NaO_2	0.99
K_2O	3.46
TiO_2	0.72
P_2O_5	NA
MnO	NA
S (total)	1.28
C (total)	0.71

Mineralogy (X-ray):

	%	Accuracy (±%)
Quartz	33	6
Mica	28	8
Kaolinite	18	7
C-V-Mo	9	3
Feldspar	2	1

Remarks: Carbonate present.

Other Properties:

pH: 9.50
P.C.E.: NA
Water of Plasticity (%): 13.6
Drying Shrinkage (%): 0.0
Dry Strength: Low
Drying Characteristics: No defects
Workability: Low Plasticity

Slow-Firing Tests:

Temp. °F	*Color*	*Hardness*	*% Shk.*	*% Absorb.*	*% App. Por.*	*Approx. Sp. Gr.*
1800	Light brown	Moh's 2	0.0	23.8	38.3	1.61
1900	Light brown	Moh's 2	0.0	24.0	37.9	1.58
2000	Brown	Moh's 3	0.0	21.8	34.7	1.59
2100	—	—	Expanded	—	—	—
2200						
2300						

Pyrometric cone equivalent: NA **Bloating test:** Negative

Remarks: Abrupt vitrification; may be limy.

Bloating Tests (Quick-Firing): NA

Other Tests: Highly effervescent with HCl.

Potential Uses: No designated ceramic use.

NORTHAMPTON COUNTY Washington Twp.

Sample Number
215-7-4

Quadrangle: Delaware Water Gap 15′; Bangor 7½′

Location: A slate quarry approximately 0.2 mile northeast of Martins Creek Junction, Pa., one mile south of Flicksville, Pa. The quarry is reached by traveling south from Flicksville, Pa., on U.S. Route 611 one mile, turning east on southeast-bearing road, and proceeding 0.15 mile to quarry located in a draw on the east side of the road.

Geologic Unit: Martinsburg Formation, Ordovician.

Description: The sample is medium-dark gray (N4) to light gray (N7), moderately weathered slate collected from a slate waste dump.

Sampled Interval: Grab sample of slate from a quarry waste dump.

Type of Material: Slate

Ceramic Testing Laboratory: Tuscaloosa

Chemical Analysis:

Analyst: Conwell	%
L.O.I. @ 1,000°C	4.86
H_2O Loss @ 110°C	0.34
Combined H_2O	4.41
SiO_2	60.02
Al_2O_3	18.39
Fe_2O_3	1.02
FeO	3.89
CaO	1.57
MgO	3.09
CO_2	0.66
Na_2O	0.99
K_2O	3.46
TiO_2	0.77
P_2O_5	NA
MnO	NA
S (total)	0.42
C (total)	0.63

Mineralogy (X-ray):

	%	Accuracy (±%)
Quartz	28	5
Mica	34	6
Kaolinite	22	7
C-V-Mo	9	3
Feldspar	2	1

Remarks:

Other Properties:

pH: 7.40
P.C.E.: NA
Water of Plasticity (%): 13.5
Drying Shrinkage (%): 0.0
Dry Strength: Low
Drying Characteristics: No defects
Workability: Low plasticity

Slow-Firing Tests:

Temp. °F	*Color*	*Hardness*	*% Shk.*	*% Absorb.*	*% App. Por.*	*Approx. Sp. Gr.*
1800	Light brown	Moh's 2	0.0	16.6	30.0	1.81
1900	Light brown	Moh's 2	0.0	15.8	28.9	1.83
2000	Brown	Moh's 2	0.0	13.8	25.5	1.85
2100	—	—	Expanded	—	—	—
2200						
2300						

Pyrometric cone equivalent: NA **Bloating test:** Negative

Remarks: Abrupt vitrification; may be limy.

Bloating Tests (Quick-Firing): NA

Other Tests: Highly effervescent with HCl.

Potential Uses: No designated ceramic use.

SCHUYLKILL COUNTY Washington Twp.

Sample Number
166-6-3

Quadrangle: Pine Grove 15′; Swatara Hill 7½′

Location: Road exposure on the north side of macadam road to Cressona, Pa., paralleling the north shore of Sweet Arrow Lake, 3.75 miles northeast of Sweet Arrow Lake.

Geologic Unit: Mahantango Formation, Devonian.

Description: Olive gray (5Y 4/1) to dark-greenish gray (5GY 4/1), thin-bedded shales are exposed for a distance of 200 feet or more along the road. The beds average 1.5 inches in thickness; some beds are fossiliferous, containing brachiopods and pelecypods. Weathering of the shale is moderate to intense with surface of the exposure and shale fragments on the slope covered with a thin layer of grayish orange clay. Iron oxide stains of dark yellow-orange (10 YR 6/6) and medium brown (5 YR 3/4) are present along fracture surfaces. The shale breaks down into tabular-shaped or platy fragments that are generally less than six inches in length.

Attitude of Bedding: At east end of exposure: N62E, 52S. Some changes in attitude occur due to folding of the rock.

Sampled Interval: Channel sample of 15 stratigraphic section.

Type of Material: ——

Ceramic Testing Laboratory: Norris

Chemical Analysis:

Analyst: Spectrochemical %

L.O.I. @ 1,000°C	4.12
H_2O Loss @ 110°C	0.49
Combined H_2O	NA
SiO_2	75.00
Al_2O_3	10.50
Fe_2O_3	4.04
FeO	0.89
CaO	0.82
MgO	1.02
CO_2	0.29
Na_2O	0.57
K_2O	2.10
TiO_2	0.93
P_2O_5	NA
MnO	NA
S (total)	< 0.02
C (total)	0.18

Mineralogy (X-ray):

	%	*Accuracy* (±%)
Quartz	48	5
Mica	30	6
Kaolinite	8	5
C-V-Mo	7	3
Feldspar	2	1

Remarks: Mineralogy indicates chemical analysis in low in Al_2O_3.

Other Properties:

pH: 7.80
P.C.E.: NA
Water of Plasticity (%): 23.0
Drying Shrinkage (%): 3.0
Dry Strength: Good
Drying Characteristics: Good; slightly wavy
Workability: Slightly plastic, fatty, short-working

Slow-Firing Tests:

Temp. °F	*Color*	*Hardness*	*% Shk.*	*% Absorb.*	*% App. Por.*	*Approx. Sp. Gr.*
1800	Red tan	Soft	5.5	5.2	—	2.57
1900	Red tan	Fair hard	6.5	5.7	—	2.57
2000	Brown	Fair hard	6.0	7.5	—	2.55
2100	Chocolate	Hard	10.5	12.1	—	2.51
2200	Dark brown	Very hard	4.0	20.9	—	1.86
2300	Black-brown	Very hard	Expanded	12.9	—	1.10

Pyrometric cone equivalent: NA **Bloating test:** Negative

Remarks: Poor color; high shrinkage; high absorption; wavy. Expansion and melting within 15°F range.

Bloating Tests (Quick-Firing): NA

Other Tests: Soluble Br. K. 1.05

Potential Uses: No designated ceramic use. Sintering tests might be run.

SCHUYLKILL COUNTY South Manheim Twp.

Sample Number
176-5-4

Quadrangle: Pottsville 15′; Auburn 7½′

Location: Road exposure on the north side of Pa. Route 895 about 0.7 mile west of Auburn, Pa.

Geologic Unit: Mahantango Formation, Devonian.

Description: Olive gray (5 Y4/1) to dark-greenish gray (5 GY 4/1), slightly to moderately weathered, medium- to massive-bedded shales are exposed along the roadway. Beds are commonly six inches to several feet thick. Certain beds are fossiliferous, and contain large numbers of brachipods and pelecypods. The exposure extends for more than 800 feet along the road and is about 20 to 40 feet high.

Attitude of Bedding: N75E, 33N

Sampled Interval: Channel sample of 20 stratigraphic feet.

Type of Material: Shale

Ceramic Testing Laboratory: Norris

Chemical Analysis:

Analyst: Spectrochemical %

L.O.I. @1,000°C	4.38
H_2O Loss @ 110°C	0.12
Combined H_2O	NA
SiO_2	69.00
Al_2O_3	13.00
Fe_2O_3	3.50
FeO	3.47
CaO	0.68
MgO	1.06
CO_2	0.55
Na_2O	0.81
K_2O	3.10
TiO_2	0.97
P_2O_5	NA
MnO	NA
S (total)	0.30
C (total)	0.31

Mineralogy (X-ray):

	%	Accuracy (±%)
Quartz	38	5
Mica	30	6
Kaolinite	15	8
C-V-Mo	8	3
Feldspar	2	1

Remarks: Mineralogy indicates chemical analysis in low in Al_2O_3.

Other Properties:

pH: 8.50
P.C.E.: NA
Water of Plasticity (%): 20.0
Drying Shrinkage (%): 0.5
Dry Strength: Good
Drying Characteristics: Mealy, short working
Workability: Mealy, short working

Slow-Firing Tests:

Temp. °F	*Color*	*Hardness*	*% Shk.*	*% Absorb.*	*% App. Por.*	*Approx. Sp. Gr.*
1800	Tan	Fair hard	1.0	7.3	—	2.54
1900	Light brown	Hard	4.5	8.4	—	2.53
2000	Light brown	Hard	6.0	16.9	—	2.48
2100	Red brown	Very hard	9.0	33.8	—	2.42
2200	Dark brown	Very hard	9.0	112.0	—	2.33
2300						

Pyrometric cone equivalent: NA **Bloating test:** Positive

Remarks: Poor color; high shrinkage; very high absorption; wavy surface; slightly rough; surface scum.

Bloating Tests (Quick-Firing):

Crushing characteristics: Good — Particle size —¾" + ½"
Drying characteristics: Good — Retention time: 15 minutes

Temp. °F	*Bulk Density*	*Lb/Ft³*	*% Absorb.*	*Remarks*
1800	—	—	—	
1900	—	—	—	
2000	1.73	108	14.3	Fair expansion, fair skin
2100	1.45	90	13.9	Fair expansion, good skin
2200	1.08	67	12.9	Good expansion, fine skin
2300				

Recommendations: Good lightweight aggregate material.

ROTARY KILN TESTS:

Raw Material:

Screen Analysis (Crushed through a hammermill with 1½" screen)

Size		*Percent Retained*
—¾"	+ ½"	43.2
—½"	+ ⅜"	16.9
—⅜"	+ 4 mesh	19.6
—4 mesh	+ 8 mesh	6.2
—8 mesh	PAN	14.1
	TOTAL	100.0

Crushing loss (—4 mesh) 20.3%

Fragment shape: Angular fragments

Firing Data:

Size range of feed: —¾ + 4 mesh — Pour weight of feed: 94.8 lb/ft³
Bloating temperature: 2000°F
Logging temperature* (*Nodules sticking together): 2050°F

Fired Material (all fired material crushed through a roll crusher)
Screen Analysis* (*ASTM Designation C 311-59T) in percentages by weight passing sieves:

Size designation	¾"	½"	⅜"	No. 4	No. 8	No. 16	No. 50	No. 100
Fine	—	—	100.0	33.4	—	4.5	2.5	2.2
Coarse	100.0	78.6	50.6	12.2	1.3	—	—	—

Loose pour weight* (*ASTM Designation C 311-59T):
Fine: 52.0 lb/ft³ — Coarse: 46.7 lb/ft³
Color: Brown

COMMENTS: Best potential for lightweight aggregate product; rounded and angular lumps; good pore structure; satisfactory crushing characteristics.

Other Tests: Soluble Br. K. 2.00

Potential Uses: Best potential for rotary kiln lightweight aggregate of excellent quality.

SCHUYLKILL COUNTY West Brunswick Twp.

Sample Number
176-6-5

Quadrangle: Pottsville 15′; Auburn 7½′

Location: Road exposure at Deer Lake, Pa., on the west side of U. S. Route 122, about 0.1 mile north of the Pa. Route 895 (west) intersection.

Geologic Unit: Mahantango Formation, Devonian.

Description: Predominantly olive gray (5 Y 3/2 with some dark gray (N3), medium- to massive-bedded shales are exposed for a distance of 300 feet along the road. The beds, some of which are fossiliferous, average several feet in thickness. The shale is slightly to moderately weathered and usually breaks into tabular fragments with hackly edges. The height of the exposure is 35 feet.

Attitude of Bedding: N28W, 17S

Sampled Interval: Composite sample of 25 stratigraphic feet.

Type of Material: Shale

Ceramic Testing Laboratory: Norris

Chemical Analysis:

Analyst: Spectrochemical	%
L.O.I. @ 1,000°C	4.37
H_2O Loss @ 110°C	0.25
Combined H_2O	NA
SiO_2	69.00
Al_2O_3	13.00
Fe_2O_3	5.11
FeO	1.99
CaO	0.37
MgO	0.97
CO_2	0.59
Na_2O	0.90
K_2O	3.20
TiO_2	0.97
P_2O_5	NA
MnO	NA
S (total)	> 0.07
C (total)	0.22

Mineralogy (X-ray):

	%	Accuracy (±%)
Quartz	37	5
Mica	37	6
Kaolinite	10	7
C-V-Mo	7	3
Feldspar	3	1

Remarks: Mineralogy indicates chemical analysis is low in Al_2O_3.

Other Properties:

pH: 7.40
P.C.E.: NA
Water of Plasticity (%): 19.0
Drying Shrinkage (%) 1.0
Dry Strength: Good
Drying Characteristics: Good; slightly wavy
Workability: Short-working

Slow-Firing Tests:

Temp. °F	Color	Hardness	% Shk.	% Absorb.	% App. Por.	Approx. Sp. Gr.
1800	Tan	Fair hard	4.5	6.9	—	2.47
1900	Tan	Hard	5.0	7.9	—	2.47
2000	Light brown	Hard	9.0	13.4	—	2.83
2100	Brown	Very hard	10.0	19.5	—	2.85
2200	Dark Brown	Steel hard	10.0	115.3	—	2.72
2300						

Pyrometric cone equivalent: NA **Bloating test:** Positive

Remarks: Good color; high shrinkage; very high absorption; slight scum.

Bloating Tests (Quick-Firing):

Crushing characteristics: Good Particle size: —¾″ + ½″

Drying characteristics: Good Retention time: 15 minutes

Temp. °F	*Bulk Density*	*Lb/Ft³*	*% Absorb.*	*Remarks*
1800	—	—	—	
1900	—	—	—	
2000	2.05	128	16.8	Fair expansion, fair skin
2100	1.50	93	17.8	Fair expansion, fair skin
2200	1.16	72	15.5	Good expansion, good skin
2300				

Recommendations: Good lightweight aggregate material.

ROTARY KILN TESTS:

Raw Material:

Screen Analysis (Crushed through a hammermill with 1½″ screen)

Size		*Percent Retained*
—¾″	+ ½″	41.2
—½″	+ ⅜″	19.2
—⅜″	+ 4 mesh	23.5
—4 mesh	+ 8 mesh	6.9
—8 mesh	PAN	9.2
	TOTAL	100.0

Crushing loss (—4 mesh) 16.1%

Fragment shape: Angular fragments

Firing Data:

Size range of feed: —¾ + 4 mesh Pour weight of feed: 101.4 lb/ft³

Bloating temperature: 2120°F

Logging temperature* (*Nodules sticking together): 2180°F

Fired Material (all fired material crushed through a roll crusher)

Screen Analysis* (*ASTM Designation C 311-59T) in percentages by weight passing sieves:

Size designation	¾″	½″	⅜″	No. 4	No. 8	No. 16	No. 50	No. 100
Fine	—	—	100.0	39.0	—	9.0	6.0	4.8
Coarse	100.0	98.0	70.0	11.0	2.6	—	—	—

Loose pour weight* (*ASTM Designation C 311-59T):

Fine: 60.0 lb/ft³ Coarse: 44.1 lb/ft³

Color: Brown

COMMENTS: Best potential for lightweight aggregate product; rounded and angular lumps; good pore structure; satisfactory crushing characteristics.

Other Tests: Soluble Br. K. 0.90

Potential Uses: Best potenital for rotary kiln lightweight aggregate of excellent quality.

SCHUYLKILL COUNTY Wayne Twp.

Sample Number
176-7-6

Quadrangle: Pottsville 15′; Friedensburg 7½′

Location: Summit Quarries, Inc., on the north side of Pa. Route 895, about 1.5 miles east of Summit Station, Pa.

Geologic Unit: Mahantango Formation, Devonian.

Description: Predominantly medium gray (5 Y 3/2) to medium-dark gray (N3), thin- to massive-bedded, sandy shales, siltstones, shaly sandstones, and sandstones are exposed in the quarry. The beds, some of which are fossilferous, range from several inches up to several feet in thickness. The exposure is slightly to moderately weathered.

Attitude of Bedding: N80E, 33N

Sampled Interval: Grab sample from rock along east wall of quarry.

Type of Material: Interbedded sandy shales, siltstones, shaly sandstones, and sandstones.

Ceramic Testing Laboratory: Norris

Chemical Analysis:

Analyst: Spectrochemical %

L.O.I. @ 1,000°C	3.65
H_2O Loss @ 110°C	0.09
Combined H_2O	NA
SiO_2	73.20
Al_2O_3	11.00
Fe_2O_3	3.80
FeO	1.95
CaO	0.38
MgO	0.88
CO_2	0.37
Na_2O	1.65
K_2O	2.40
TiO_2	1.00
P_2O_5	NA
MnO	NA
S (total)	0.16
C (total)	0.22

Mineralogy (X-ray):

	%	*Accuracy (±%)*
Quartz	47	5
Mica	25	6
Kaolinite	17	8
C-V-Mo	0	
Feldspar	3	1

Remarks: Mineralogy indicates chemical analysis is low in Al_2O_3.

Other Properties:

pH: 8.20
P.C.E.: NA
Water of Plasticity (%): 22.0
Drying Shrinkage (%): 0.0
Dry Strength: Good
Drying Characteristics: Fair; slgihtly wavy; scum
Workability: Fairly plastic; smooth; short-working

Slow-Firing Tests:

Temp. °F	*Color*	*Hardness*	*% Shk.*	*% Absorb.*	*% App. Por.*	*Approx. Sp. Gr.*
1800	Tan	Fair hard	0.5	6.5	—	2.54
1900	Light brown	Fair hard	2.5	7.5	—	2.23
2000	Brown	Hard	5.0	8.9	—	2.23
2100	Dark brown	Very hard	10.0	19.5	—	2.24
2200	Black-brown	Steel hard	10.0	32.3	—	2.11
2300						

Pyrometric cone equivalent: NA **Bloating test:** Positive

Remarks: Fair color; high shrinkage; high absorption; scum; wavy surface.

Bloating Tests (Quick-Firing):

Crushing characteristics: Good — Particle size: —¾″ + ½″
Drying characteristics: Good — Retention time: 15 minutes

Temp. °F	*Bulk Density*	*Lb/Ft³*	*% Absorb.*	*Remarks*
1800	—	—	—	
1900	—	—	—	
2000	2.10	131	18.5	Slight expansion
2100	1.37	85	14.0	Good expansion—fair skin
2200	1.21	75	12.8	Good expansion—good skin
2300				

ROTARY KILN TESTS:

Raw Material:

Screen Analysis (Crushed through a hammermill with 1½″ screen)

Size		*Percent Retained*
—¾″	+ ½″	49.9
—½″	+ ⅜″	19.1
—⅜″	+ 4 mesh	15.2
—4 mesh	+ 8 mesh	2.9
—8 mesh	PAN	12.9
	TOTAL	100.0

Crushing loss (—4 mesh) 15.8%

Fragment shape: Angular

Firing Data:

Size range of feed: —¾ + 4 mesh — Pour weight of feed: 82.0 lb/ft³

Bloating temperature: 2020°F

Logging temperature* (*Nodules sticking together): 2050°F

Fired Material (all fired material crushed through a roll crusher)

Screen Analysis* (*ASTM Designation C 311-59T) in percentages by weight passing sieves:

Size designation	¾″	½″	⅜″	No. 4	No. 8	No. 16	No. 50	No. 100
Fine	—	—	100.0	68.0	—	27.3	12.9	9.4
Coarse	100.0	68.0	56.0	33.0	20.4	—	—	—

Loose pour weight* (*ASTM Designation C 311-59T):

Fine: 62.5 lb/ft³ — Coarse: 55.0 lb/ft³

Color: Dark brown

COMMENTS: Marginal for lightweight aggregate; undesirable mixture of bloating and non-bloating material; angular and tabular fragments; poor crushing; fine pore structure.

Other Tests: Soluble Br. K. 0.90

Potential Uses: Marginal for lightweight aggregate. Lightweight aggregate made from this material may range from good to fair quality depending upon processing control.

Remarks: Presently being quarried for crushed stone.

YORK COUNTY Conowago Twp.

Sample Number
148-9-3

Quadrangle: New Cumberland 15′; Dover 7½′

Location: Exposure on the south side of a secondary road connecting Pa. Route 921 and Butter Road to the west. The exposure is 0.9 mile east of Eastmont, Pa., 0.65 mile north-northeast of Suburban Memorial Gardens, and 0.65 mile west of Pa. Route 921.

Geologic Unit: New Oxford Formation, Triassic.

Description: Pale reddish brown (10 R 5/4), thin-bedded shales are interbedded with a few silty shales in the drainage ditch. Individual beds measure less than an inch in thickness and are only slightly weathered. The sampling site is approximately on strike with the Glen-Gery Shale Brick Corp. quarry located northwest of Dover, Pa.

Attitude of Bedding: N35-50E, 15-25S

Sampled Interval: Composite sample of 8 stratigraphic feet.

Type of Material: Shale

Ceramic Testing Laboratory: Tuscaloosa

Chemical Analysis:

Analyst: Conwell	%
L.O.I. @ 1,000°C	4.68
H_2O Loss @ 110°C	1.35
Combined H_2O	4.60
SiO_2	58.94
Al_2O_3	18.09
Fe_2O_3	7.81
FeO	0.50
CaO	1.41
MgO	2.57
CO_2	0.06
Na_2O	1.65
K_2O	2.02
TiO_2	0.90
P_2O_5	NA
MnO	NA
S (total)	0.07
C (total)	0.07

Mineralogy (X-ray):

	%	*Accuracy (±%)*
Quartz	28	5
Mica	43	6
Kaolinite	0	—
C-V-Mo	13	3
Feldspar	6	2
Remarks:		

Other Properties:

pH: 5.50
P.C.E.: NA
Water of Plasticity (%): 16.7
Drying Shrinkage (%): 0.0
Dry Strength: Low
Drying Characteristics: Satisfactory
Workability: Mealy; low plasticity

Slow-Firing Tests:

Temp. °F	*Color*	*Hardness*	*% Shk.*	*% Absorb.*	*% App. Por.*	*Approx. Sp. Gr.*
1800	Dark tan	Moh's 2	0.0	13.7	—	1.87
1900	Dark tan	Moh's 3	0.0	12.3	—	1.90
2000	Brown	Moh's 4	2.5	8.5	—	2.05
2100	Dark brown	Moh's 7	7.5	1.3	—	2.28
2200	Overfired	—	—	—	—	—
2300	Overfired	—	—	—	—	—

Pyrometric cone equivalent: NA **Bloating test:** Negative

Remarks: Short-working; fires to good brown.

Bloating Tests (Quick-Firing): NA

Other Tests: None

Potential Uses: Face brick.

YORK COUNTY Conowago Twp.

Sample Number
148-9-4

Quadrangle: New Cumberland 15′; Dover 7½′

Location: Road exposure on the north side of Pa. Route 921 about 0.4 mile east of Zions View, Pa.

Geologic Unit: New Oxford Formation, Triassic.

Description: A predominantly pale-reddish brown (10 R 5/4), slightly weathered, sequence of mudstones, fissile shales, and siltstones, 9 and 15 inches thick respectively, were sampled near the crest of the hill, starting under telephone pole ME 1448 CE; 330L-65K. The stratigraphic sequence is as follows: mudstones (3 feet), fissile shale (7 feet), siltstones (3 feet), and fissile shale (7 feet), for a total of 20 stratigraphic feet. The exposure measured about 250 feet along the road.

Attitude of Bedding: N45E, 18N

Sampled Interval: Composite sample of 20 stratigraphic feet.

Type of Material: Shale

Ceramic Testing Laboratory: Tuscaloosa

Chemical Analysis:

Analyst: Conwell	%
L.O.I. @ 1,000°C	6.99
H_2O Loss @ 110°C	1.75
Combined H_2O	4.10
SiO_2	50.14
Al_2O_3	18.53
Fe_2O_3	8.26
FeO	1.15
CaO	4.33
MgO	3.22
CO_2	2.43
Na_2O	1.81
K_2O	2.26
TiO_2	0.91
P_2O_5	NA
MnO	NA
S (total)	None
C (total)	0.43

Mineralogy (X-ray):

	%	Accuracy (±%)
Quartz	21	6
Mica	49	10
Kaolinite	4	2
C-V-Mo	11	3
Feldspar	5	2

Remarks:

Other Properties:

pH: 7.10

P.C.E.: NA

Water of Plasticity (%): 14.8

Drying Shrinkage (%): 0.0

Dry Strength: Low

Drying Characteristics: Satisfactory

Workability: Gritty; non-plastic

Slow-Firing Tests:

Temp. °F	Color	Hardness	% Shk.	% Absorb.	% App. Por.	Approx. Sp. Gr.
1800	Light brown	Moh's 2	0.0	16.9	—	1.73
1900	Light brown	Moh's 2	0.0	17.5	—	1.73
2000	Light brown	Moh's 4	0.0	12.5	—	1.84
2100	Dark brown	Moh's 6	0.0	4.2	—	1.88
2200	Overfired	—	—	—	—	—
2300	Overfired	—	—	—	—	—

Pyrometric cone equivalent: NA **Bloating test:** Negative

Remarks: Short-working; low green strength; narrow firing range.

Bloating Tests (Quick-Firing): NA

Other Tests: None

Potential Uses: No designated ceramic use.

YORK COUNTY Dover Twp.

Sample Number
149-2-2

Quadrangle: Hanover 15′; Abbottstown 7½′

Location: Road cut about 0.8 mile east-southeast of Davidsburg, Pa., along the northwest side of the macadam road leading from Dover to Abbottstown, Pa.

Geologic Unit: New Oxford Formation, Triassic.

Description: Pale reddish brown (10 R 5/4), slightly to moderately weathered, thin-bedded shales and siltstones are exposed in the road cut. The exposure is about 8 feet high with 2 feet of soil overburden.

Attitude of Bedding: Essentially horizontal

Sampled Interval: Channel sample of 7 stratigraphic feet.

Type of Material: Shale and Siltstone

Ceramic Testing Laboratory: Norris

Chemical Analysis:

Analyst: Spectrochemical	%
L.O.I. @ 1,000°C	5.38
H_2O Loss @ 110°C	1.31
Combined H_2O	NA
SiO_2	63.50
Al_2O_3	14.50
Fe_2O_3	8.43
FeO	0.05
CaO	0.73
MgO	1.44
CO_2	0.44

Mineralogy (X-ray):

	%	Accuracy (±%)
Quartz	34	6
Mica	46	8
Kaolinite	0	—
C-V-Mo	13	3
Feldspar	2	1

Remarks: Mineralogy indicates chemical analysis is low in Al_2O_3.

Chemical Analysis:

Analyst: Spectrochemical %

Na_2O	1.26
K_2O	3.70
TiO_2	0.98
P_2O_5	NA
MnO	NA
S (total)	> 0.02
C (total)	0.14

Other Properties:

pH: 5.82
P.C.E.: NA
Water of Plasticity (%): 19.8
Drying Shrinkage (%): 0.0
Dry Strength: Good
Drying Characteristics: Fair; slight warping and crazing
Workability: Mealy; short-working

Slow-Firing Tests:

Temp. °F	*Color*	*Hardness*	*% Shk.*	*% Absorb.*	*% App. Por.*	*Approx. Sp. Gr.*
1800	Light brown	Fair hard	4.5	6.7	—	2.59
1900	Light brown	Hard	4.5	8.8	—	2.55
2000	Red brown	Very hard	7.5	20.2	—	2.54
2100	Chocolate	Very hard	7.5	25.1	—	2.50
2200	Dark brown	Very hard	7.5	70.5	—	2.10
2300	Black-brown	Very hard	Expanded	51.0	—	1.68

Pyrometric cone equivalent: NA **Bloating test:** Negative

Remarks: Fair color, high absorption, slight warping and scumming, very short melting range. Potential use might be sintered lightweight aggregate.

Bloating Tests (Quick-Firing): NA

Other Tests: Soluble Br. K. 0.90

Potential Use: Possible raw material for sintered lightweight aggregate.

YORK COUNTY Jackson Twp.

Sample Number
149-2-3

Quadrangle: Hanover 15′; West York 7½′

Location: Exposure 0.5 mile east of Thomasville, Pa., on the west side of a road leading south from U. S. Route 30. The sampling site is approximately 50 yards south of U. S. Route 30 behind the C. P. Craumer, Inc. Office.

Geologic Unit: Kinzers Formation, Cambrian.

Description: The exposure consists of light olive gray (5 Y 6/1), unweathered, subfissile, shale which breaks into oblong cubical pieces. The outcrop is slightly weathered with manganese and iron staining present along fractures. There are approximately 2 feet of overburden composed of clay and shale chips resulting from the weathering of the upper portion of the Kinzer shale.

Attitude of Bedding: N37W, 18-37NE

Sampled Interval: Channel sample of 10 stratigraphic feet.

Type of Material: Shale and clay shale

Ceramic Testing Laboratory: Tuscaloosa

Chemical Analysis:

Analyst: Conwell	%
L.O.I. @ 1,000°C	4.62
H_2O Loss @ 110°C	0.93
Combined H_2O	4.59
SiO_2	59.16
Al_2O_3	17.94
Fe_2O_3	4.83
FeO	1.69
CaO	0.10
MgO	3.29
CO_2	0.00
Na_2O	0.39
K_2O	6.01
TiO_2	0.97
P_2O_5	0.16
MnO	0.01
S (total)	0.00
C (total)	0.11

Mineralogy (X-ray):

	%	Accuracy (±%)
Quartz	33	5
Mica	51	6
Kaolinite	0	
C-V-Mo	9	3
Feldspar	2	1

Remarks:

Other Properties:

pH: 5.8
P.C.E.: NA
Water of Plasticity (%): 17.1
Drying Shrinkage (%): 0.0
Dry Strength: Low
Drying Characteristics: No drying defects
Workability: Low plasticity

Slow-Firing Tests:

Temp. °F	*Color*	*Hardness*	*% Shk.*	*% Absorb.*	*% App. Por.*	*Approx. Sp. Gr.*
1800	Tan	Poor bond	—	—	—	—
1900	Tan	Moh's 3	0.0	18.1	31.6	1.75
2000	Light brown	Moh's 4	5.0	9.4	18.9	2.02
2100	Dark brown	Moh's 5	7.5	1.4	3.1	2.19
2200	Melted	—	—	—	—	—
2300						

Pyrometric cone equivalent: NA **Bloating test:** Negative

Remarks: Low dry strength. Poor ceramic bond. Poor color. Not suitable for use as principle component in vitreous clay products.

Bloating Tests (Quick-Firing):

Crushing characteristics: Angular Particle size: ¾" lumps
Drying characteristics: NA Retention time: 15 minutes

Temp. °F	*Bulk Density*	*Lb/Ft³*	*% Absorb.*	*Remarks*
1800				
1900				
2000	1.74	109	3.1	No expansion
2100	1.26	78	2.9	Slight expansion
2200	1.15	72	2.1	Slight expansion
2300				

Recommendations: Not suitable for lightweight aggregate (heavy).

Other Tests: Not effervescent with HCl.

Semi-quantitative spectrographic analysis indicated Ba in amounts >0.1%, and Sr, Zr and V in amounts >0.001% but <0.01%. Other elements such as Zn, Cu, Cr, and Ni, if present, are less than 0.001%.

Potential Uses: No designated ceramic use.

POTENTIAL USES COMPILED BY COUNTY, LOCATION, AND GEOLOGIC UNIT

Table 7 is a compilation according to the potential uses. The data for each sample evaluated during this investigation are listed by stratigraphic unit and county. The stratigraphic units are presented in order of geologic age, from oldest to youngest. The sample number and county designation serve as a cross reference to the data sheets presented in the Individual Sample Data section.

This table serves as a guide to geologic units having specific ceramic use(s) and to the geographic areas or counties in which they occur. A geologic unit for which a use is indicated from the evaluation of several samples and which has some geographic range, merits further consideration. On the other hand, geologic units which did not test favorably for ceramic use cannot necessarily be eliminated from future consideration, because an insufficient number of samples may have prevented accurate evaluation.

Table 7. Use of Shales and Clay

Individual Sample Data Page	*Formation*	*County*	*Sample Number*	*No. Designated Ceramic Use*	*Face Brick*	*Decorative Brick*	*Structural Tile*
	Precambrian						
	Sericite Schist	Adams	128-9-2	X			
			129-2-6	X			
			129-3-7	X			
			129-3-8				
			129-7-3				
			129-7-4	X			
			129-7-5	X			
	Precambrian						
	Pyrophyllite		138-7-3A	X			
			138-7-3B				
	Precambrian Anorthosite	Chester	188-8-4	X			
	Precambrian Metarhyolite	Cumber-land	138-7-4	X			
	Cambro-Ordovician Pegmatite		199-7-1				
	Kinzers	York	149-2-3	X			
		Lancaster	168-8-11				
			168-8-12				
			178-8-5				
	Hershey	Berks	177-5-5		X		X
	Cocalico	Lancaster	168-3-8A				
			168-3-8B				
			168-4-10A	X			
			168-4-10B	X			
			168-5-9	X			
	Ordovician Martinsburg	Franklin	109-6-4A	X			
			109-6-4B	X			
			109-6-5	X			
			109-6-7				
			109-9-6				
			109-9-8		X		
		Cumber-land	118-6-2		X		
		Franklin	118-8-1				
			119-1-1				
			119-1-5				
			119-1-9		X		
			119-4-4				
			119-4-7				
			119-4-8				
			119-7-2				
			119-7-3				
			119-7-6		X		
		Cumber-land	128-1-4		X		
			128-3-3		X		
			137-8-3A				
			137-8-3B				
			137-9-2	X			
			137-9-4		X		

, County, and Sample Number

Low Duty Refractories	*Lightweight Aggregate* Fair	Good	Excellent	Not Promising	Sinter	Plus Bloat	Stoneware (including Pottery)	Filler
								X
						X		
						X		
X								
						X		
						X		
						X		
			X			X		
			X			X		
	X					X		
		X				X		
	X					X		
	X					X		
						X		
				X				
						X		
	X					X		
	X					X		
						X		
	X					X		
				X		X		
		X				X		
	X					X		
	X					X	X	
						X		
	X							

Table 7. Use of Shales and Clays by

Individual Sample Data Page	*Formation*	*County*	*Sample Number*	*No. Designated Ceramic Use*	*Face Brick*	*Decorative Brick*	*Structural Tile*
	Ordovician Martinsburg (cont.)	Cumberland	138-2-6		X		
			147-7-1				
		Dauphin	147-8-4	X			
			147-8-6				
			147-8-7		X		
			147-9-2		X		
			147-9-3		X		
			147-9-5		X		
		Cumberland	148-1-2				
		Dauphin	148-3-6		X		
			148-3-7		X		
			157-5-6				
			157-5-7		X		
			157-8-8		X		
			157-8-9				
		Lebanon	167-1-5				
			167-1-6	X			
			167-1-7				
		Berks	176-8-7	X			
			177-2-3				
			177-2-4				
		Lehigh	186-3-7	X			
		Berks	186-5-3		X	X	
			186-5-6				
		Lehigh	186-5-8				
			186-6-4			X	
			186-6-5		X		X
		Berks	186-7-10		X		
			186-9-9		X		
		Northampton	195-9-4				
			195-9-5				
		Lehigh	196-5-3	X			
			196-7-4	X			
		Northampton	205-6-7				
			205-8-5				
			205-9-6				
			206-1-1	X			
			206-1-2	X			
			215-2-3	X			
			215-7-4	X			

...y, and Sample Number—(continued).

Low Duty Refractories	Lightweight Aggregate: Fair	Lightweight Aggregate: Good	Lightweight Aggregate: Excellent	Not Promising	Sinter	Plus Bloat	Stoneware (including Pottery)	Filler
			X			X		
	X					X	X	
			X			X		
		X				X		
	X					X		
				X		X		
						X		
						X		
	X					X		
	X					X		
						X		
						X		
	X					X		
	X					X		
						X		
						X		
						X		
						X		
	X					X		
	X					X		

Table 7. *Use of Shales and Clays by*

Individual Sample Data Page	*Formation*	*County*	*Sample Number*	*No. Designated Ceramic Use*	*Face Brick*	*Decorative Brick*	*Structural Tile*
	Martinsburg (cont.)	Franklin	109-2-2	X			
			109-2-3		X		
			109-5-1	X			
	Mahantango		99-9-1				
			991-2-2				
		Lebanon	157-3-5		X		
		Schuylkill	166-6-3				
			176-5-4				
			176-6-5				
			176-7-6				
	Ridgeley-Bowmantown	Monroe	205-4-9		X		
	New Scotland		205-5-3				
	Buttermilk Falls		205-5-4				
			205-6-8				X
	New Oxford	York	148-9-3		X		
			148-9-4	X			
			149-2-2				
	Stockton	Berks	188-2-2			X	
		Bucks	217-6-10	X			
	Gettysburg	Adams	139-1-5A				
			138-1-5B				
			139-1-5C				
			139-1-5D			X	
			139-1-5E				
			139-4-6			X	
			139-4-7A	X			
			139-4-7B				
			139-5-12A		X		
			139-5-12B			X	
			139-5-12C		X		X
			139-7-8			X	
			139-10-10			X	
			139-10-11		X		
	Lockatong	Montgomery	198-2-2	X			
			198-2-2A	X			
			198-2-2B				
		Chester	198-6-1A		X		
			198-6-1B		X		
		Montgomery	207-5-3	X			
			207-7-2A				
			207-7-2B		X		

…ty, and Sample Number—(continued).

Low Duty Refractories	Lightweight Aggregate: Fair	Lightweight Aggregate: Good	Lightweight Aggregate: Excellent	Not Promising	Sinter	Plus Bloat	Stoneware (including Pottery)	Filler
	X					X		
			X			X		
					?			
			X			X		
			X			X		
		X				X		
?							?	
?							?	
					?			
				X		X		
				X		X		
				X		X		
				X		X		
				X		X		
				X				
				X		X		
					X	X	X	
						X		
						X		
						X		
						X		
						X		
				X		X		
						X		

Table 7. *Use of Shales and Clays b*

Individual Sample Data Page	*Formation*	*County*	*Sample Number*	*No. Designated Ceramic Use*	*Face Brick*	*Decorative Brick*	*Structural Tile*
	Lockatong (cont.)	Montgomery (cont.)	208-3-4	X			
			208-5-2A		X		
			208-5-2B				
			208-5-2C				
		Bucks	217-2-4				
			217-2-4A(1)	X			
			217-2-4B(1)				
			217-2-4C(1)				
			217-3-8				
			217-3-9				
			217-6-1	X			
			217-6-1A				
			217-6-2				
			217-7-1	X			
			217-8-6	X			
			217-8-7				
			217-9-11	X			
			217-9-12				
		Montgomery	218-1-1A	X			
			218-1-1B				
			218-1-2	X			
		Bucks	227-8-1				
	Brunswick	Berks	118-1-3			X	
			197-7-2		X		
		Montgomery	198-2-2C				
			207-8-4	X			
			208-2-3	X			
		Bucks	216-8-1	X			
			216-9-2	X			
			217-2-4A(1)	X			
			217-2-5	X			
			217-2-5A	X			
			217-3-3	X			

…, and Sample Number—(continued).

Low Duty Refractories	*Lightweight Aggregate*			*Not Promising*	*Sinter*	*Plus Bloat*	*Stoneware (including Pottery)*	*Filler*
	Fair	*Good*	*Excellent*					
				X		X		
				X		X		
				X		X		
						X		
				X[1]		X		
				X		X		
			X			X		
			X			X		
					X	X		
						X		
						X		
			X			X		
			X			X		
						X		
						X		
				X		X		
						X		
						X		
						X		
				X[1]				

Note: (1) Sample 217-2-4A, 217-2-4B and 217-2-4C collected as one sample for rotary kiln testing.

EVALUATION OF ANALYTICAL DATA

INTRODUCTION

In the ensuing correlations of variables, one major point must be kept in mind: the correlations are limited to the raw analytical data in this report. It must also be remembered that the stated potential for utilization of a unit is based on the test methods outlined here as used by the United States Bureau of Mines laboratories. This is important because it means that data not available, or correlations not illustrated, may influence potential economic use to a significant extent. For example, the evaluations do not include the potential use of any source material resulting from raw material blending or beneficiation. In many cases, proper blending of one unit with another may allow the utility of an otherwise unacceptable raw material. Varying production methods may change the character of the end product, and hence change its potential for a specific use. In addition to these cautionary reminders, there are several possibly important variables that have not been evaluated, such as extent of weathering, impurities (minor mineral components), grain size, texture, etc. Other limitations will be discussed subsequently. In many respects the correlations presented here indicate non-use, rather than potential use, of raw materials. In spite of the many absolute measurements, judgments are still required to evaluate economic utility.

Within the limits of these precautions, a large number of physical, chemical, and mineralogical variables have been integrated in an attempt to establish criteria for rapid evaluation of shales and clays. The correlations presented are primarily concerned with the practical aspects of raw materials utilization; however, several are discussed which are largely of geological interest. Selected parameters have been plotted to determine range limits and optimal characteristics primarily with respect to use and to raw material rock type.

The following types of correlations with use are presented in succeeding sections:

1. Mineralogical composition
2. Geologic rock type
3. Selected physical properties tests
4. Chemical composition

CORRELATION LIMITATIONS

The validity of the correlations presented in the succeeding sections may be affected by the following limitations, although in most cases

these limitations will not affect the general conclusions regarding utility or the exploitation of potential shale and clay deposits.

1. Although every effort was made to collect a representative ten pound sample (gross) at each location, it may not be representative of the entire exposure, or adequately represent the extension of a unit beyond the outcrop area.

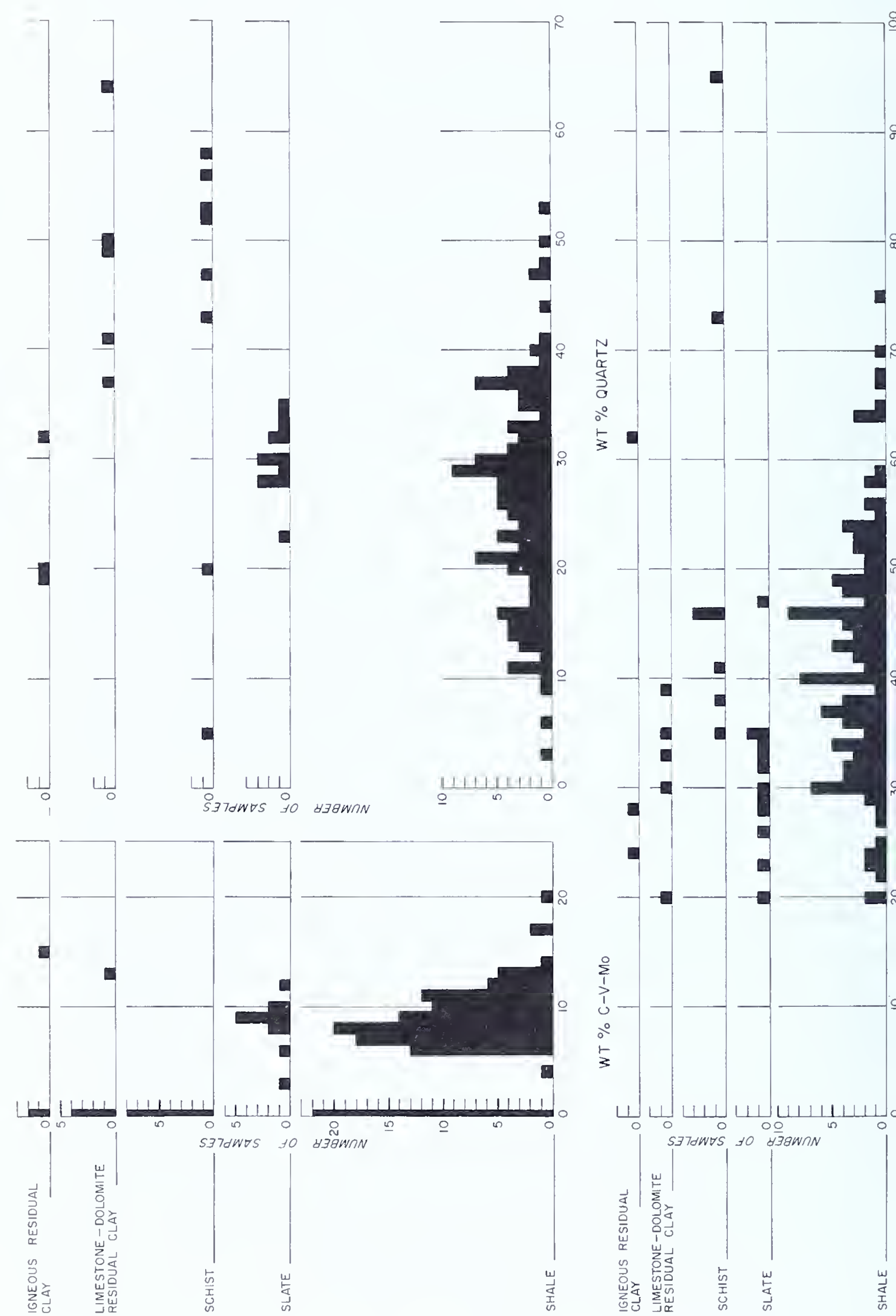
2. Mineralogical, chemical, and physical tests contain some slight margin of error which could, to a minor degree, affect the results; however, these errors are probably within the limits of error of significant use evaluation.

3. Because two separate U. S. Bureau of Mines laboratories were involved in the ceramic testing of the samples, the terminology and testing procedures vary. Furthermore, some samples in this report have *not* been tested for all possible uses, nor are the "use" categories the same as previously published (O'Neill and others, 1965). Those specific uses which have been designated for each sample are based on limited testing and a significant amount of judgment (e.g. shape of grains and fragments, cohesiveness, color, etc.). Some samples therefore may be potential raw material for uses other than the assigned use. The effect of mixing or blending raw materials on their potential usefulness has not been considered.

4. Correlations between two variables may be oversimplification of a multiple interdependence of three or more variables. For example, shales may have a different component (C) range (i.e., quartz, mica, CO_2, etc.) for potentially good lightweight aggregate then slates for the same quality aggregate. The result of simplifying to binary correlations will be to increase the range of any one variable with respect to potential use.

Excluding the limitations of types of test procedures and lack of blending, multiple interdependence is perhaps the most serious source of error as well as the most difficult to assess. If there is any oversimplification in the correlation graphs, the most likely source of error will be the influence on potential use of each rock type (texture, color, cleavage or parting planes, grain size, porosity, etc.) for a specific component (C) such as quartz, mica, total iron, etc. If, for example, the range for the component quartz for a good lightweight aggregate from shales differs from the range in slates, it will only be apparent if there is a sufficient number of samples of each rock type to bracket the quartz range. In order to express a limit of confidence for the correlations, each variable ideally should be bracketed by samples which lie outside the component range for any given rock type and specific use.

The mineral variation for all analyzed samples of each rock type is shown as a series of histograms (Figure 9). By comparing the mineral


WT % C-V-Mo
WT % QUARTZ
NUMBER OF SAMPLES
IGNEOUS RESIDUAL CLAY
LIMESTONE-DOLOMITE RESIDUAL CLAY
SCHIST
SLATE
SHALE

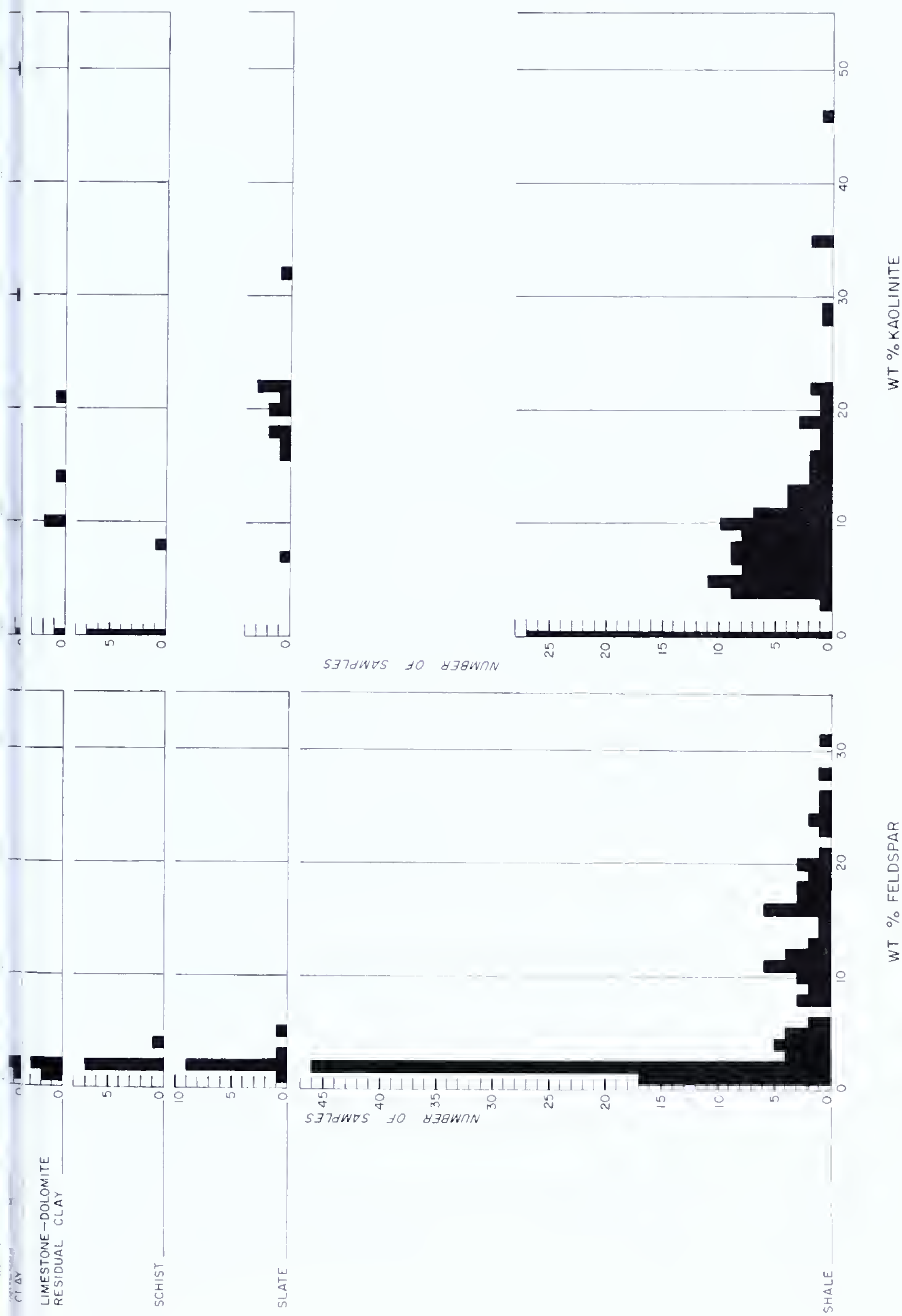


Figure 9. Histograms of mineralogical composition for all rock types studied.

component (C) ranges in these histograms with the binary graphs of mineralogy, CO_2, or pH, plotted against specific use (Figures 10-15), the number of samples which fall above, below, and within, a given range for a given component can be determined (Table 8). For example, shale samples designated as being potentially good lightweight aggregate have upper and lower limits of quartz content. This defines the quartz component range for that specific use and rock type. Considering all samples of shale in this report, many samples will have a quartz content too high or too low to fall within the defined range for a specified use. The more samples which fall above and below the component range, the greater is the confidence that can be placed in the definition of that range limit. Table 8 presents this numerical expres-

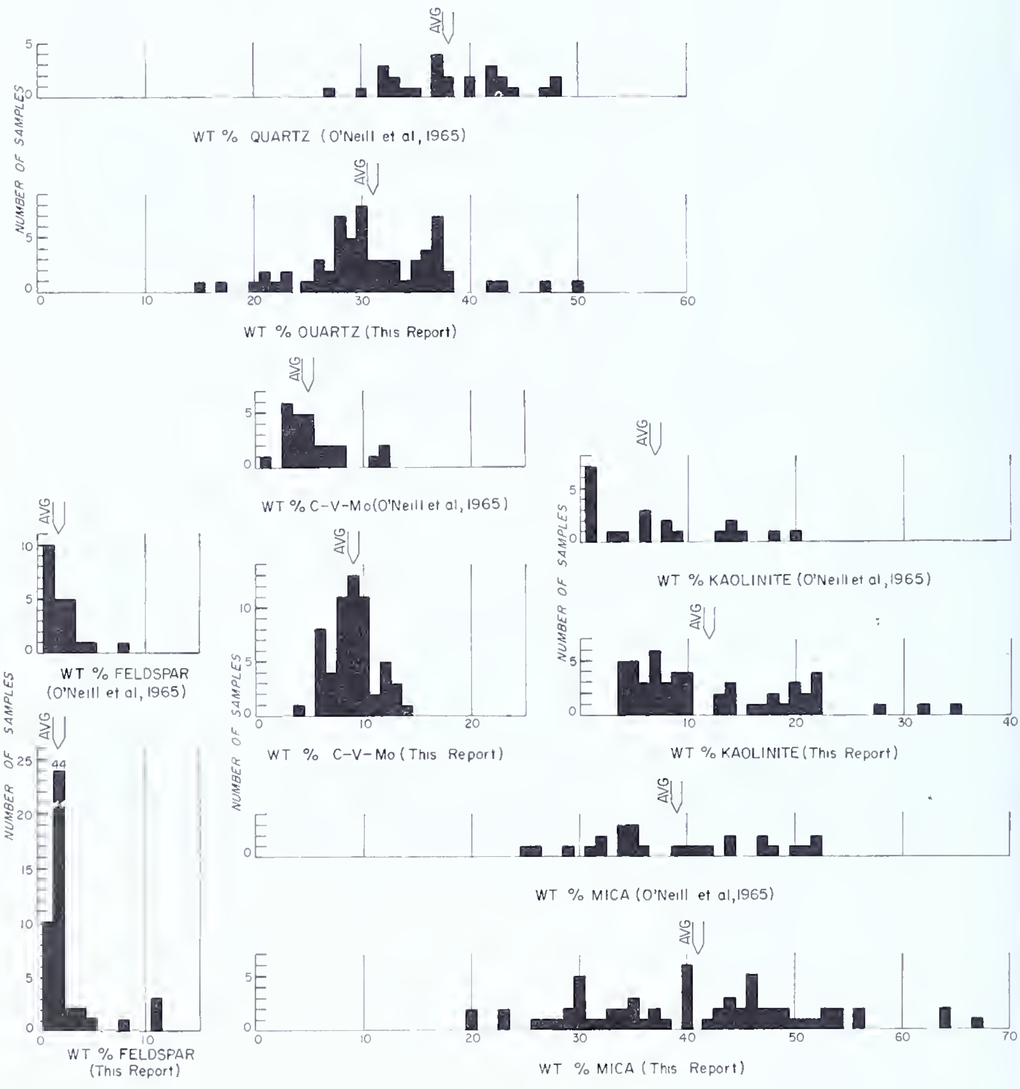
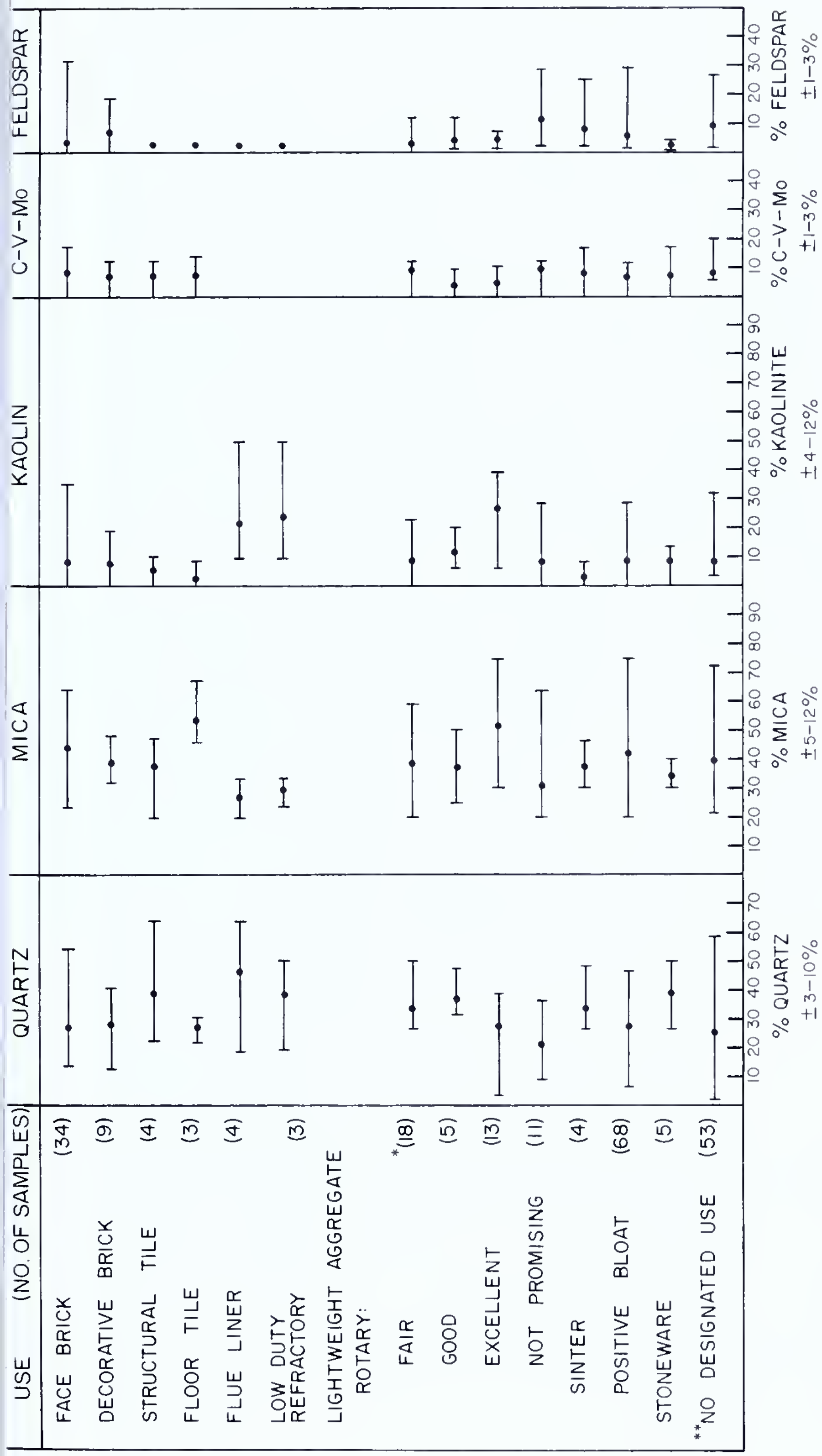


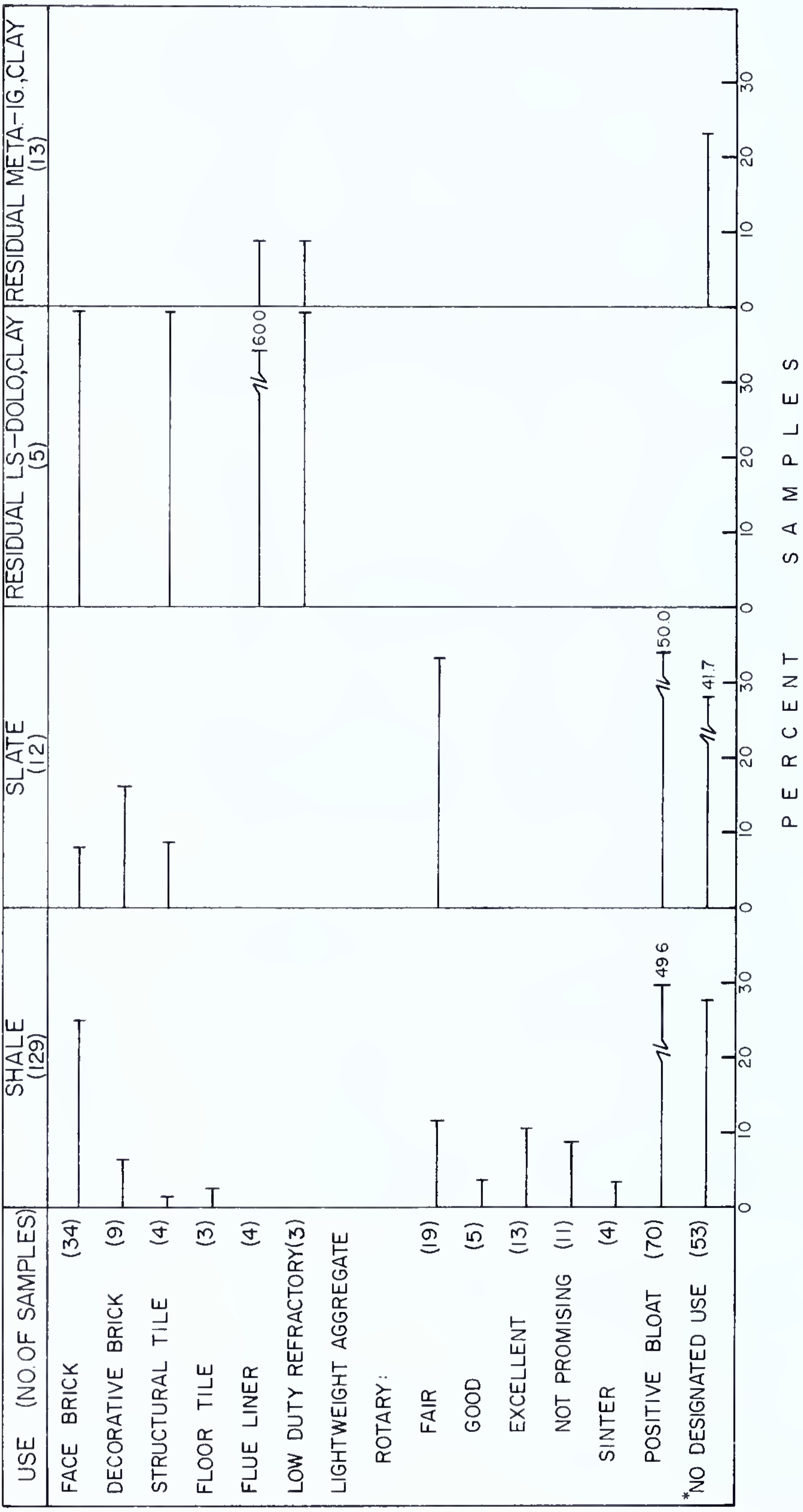
Figure 10. Comparative mineralogy of the Martinsburg Formation.



*Sample 119-4-8, no quantitative mineral data available

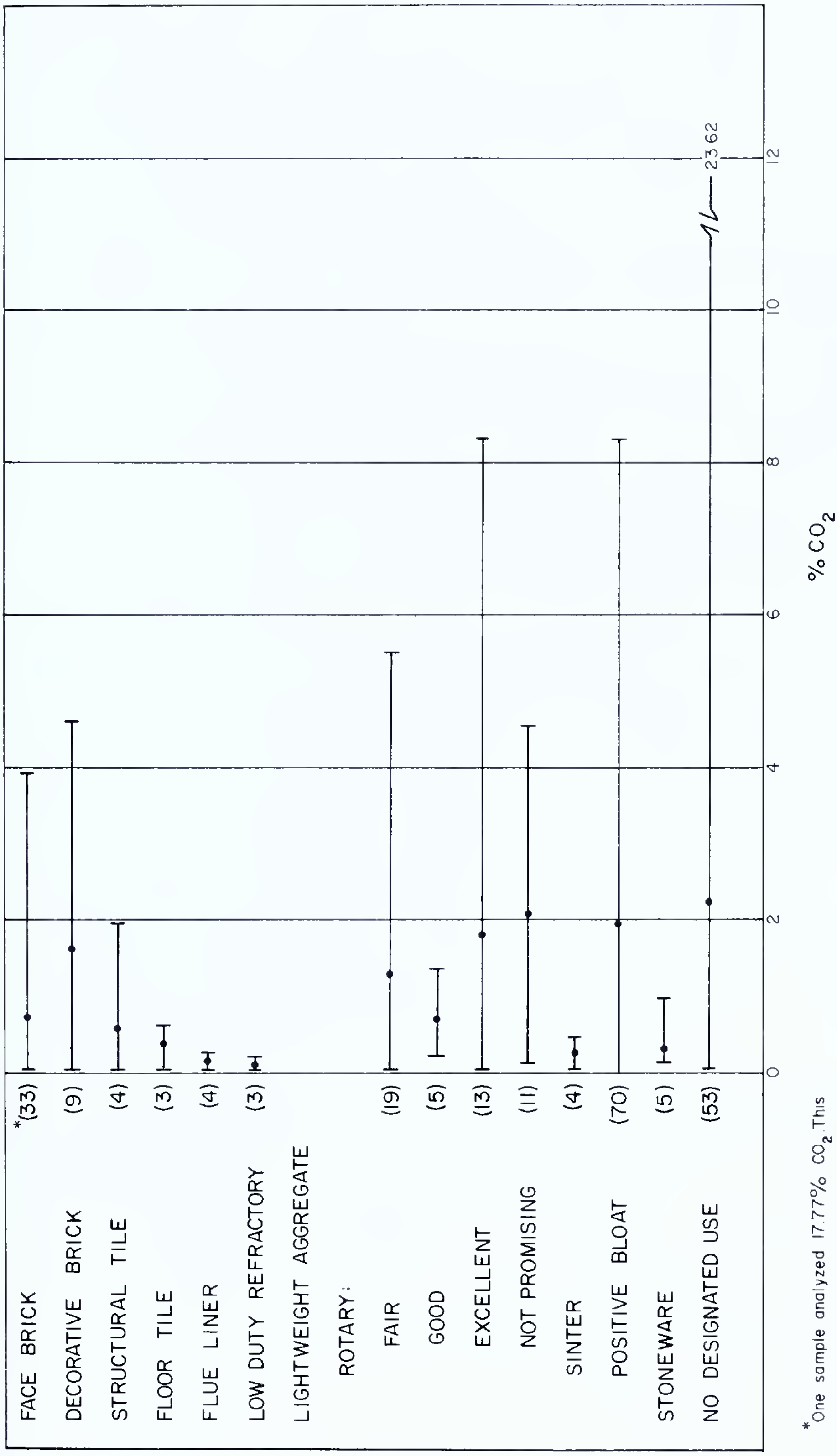
**Includes 3 samples having possible filler potential, but not tested ceramically

Figure 11. Mineralogy versus use.



*Includes 3 samples having filler potential, but not tested ceramically.

Figure 12. Rock type versus use.



*One sample analyzed 17.77% CO_2. This sample was not used in Face Brick computations for Carbon Dioxide

Figure 13. CO_2 versus use.

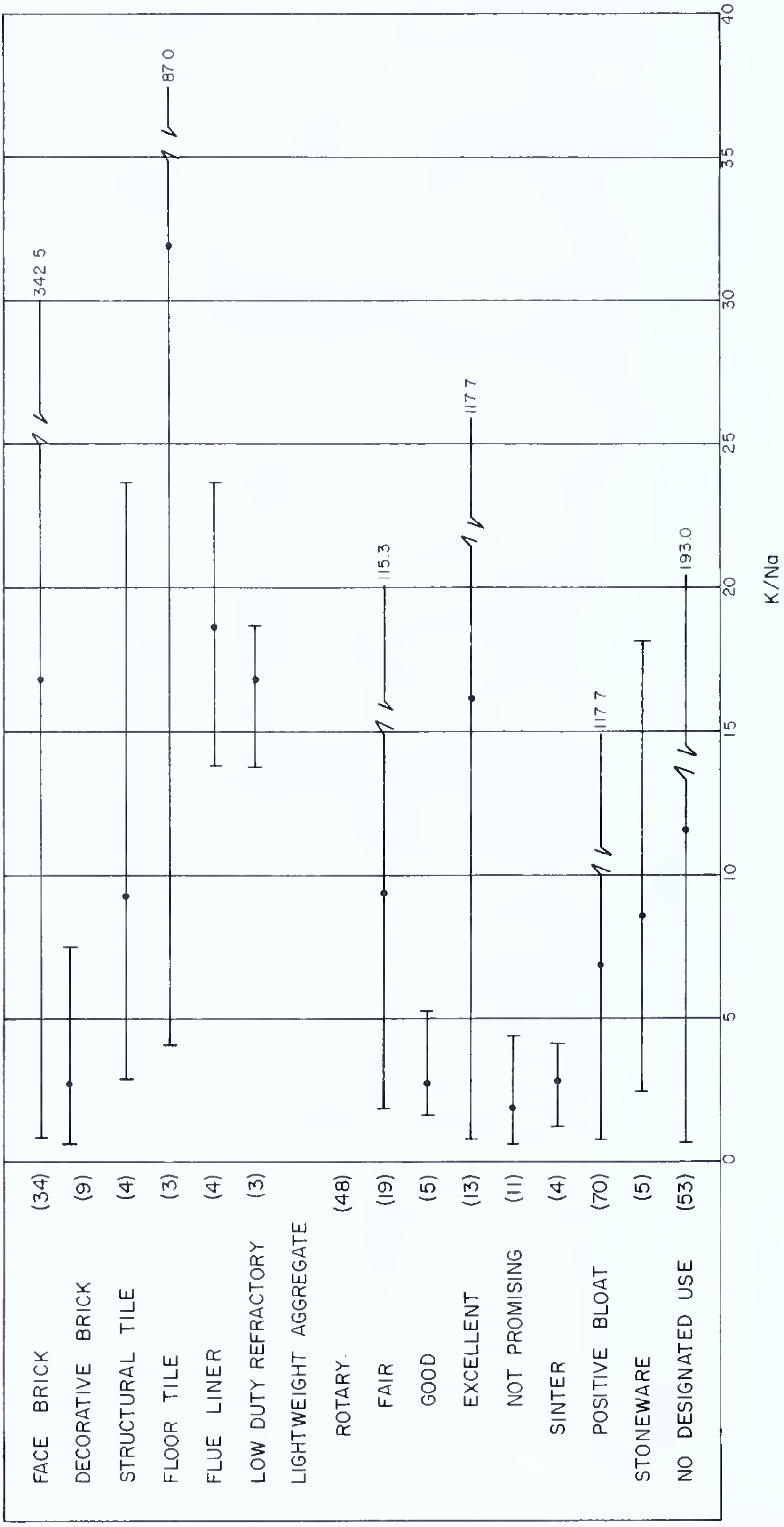


Figure 14. K/Na versus use.

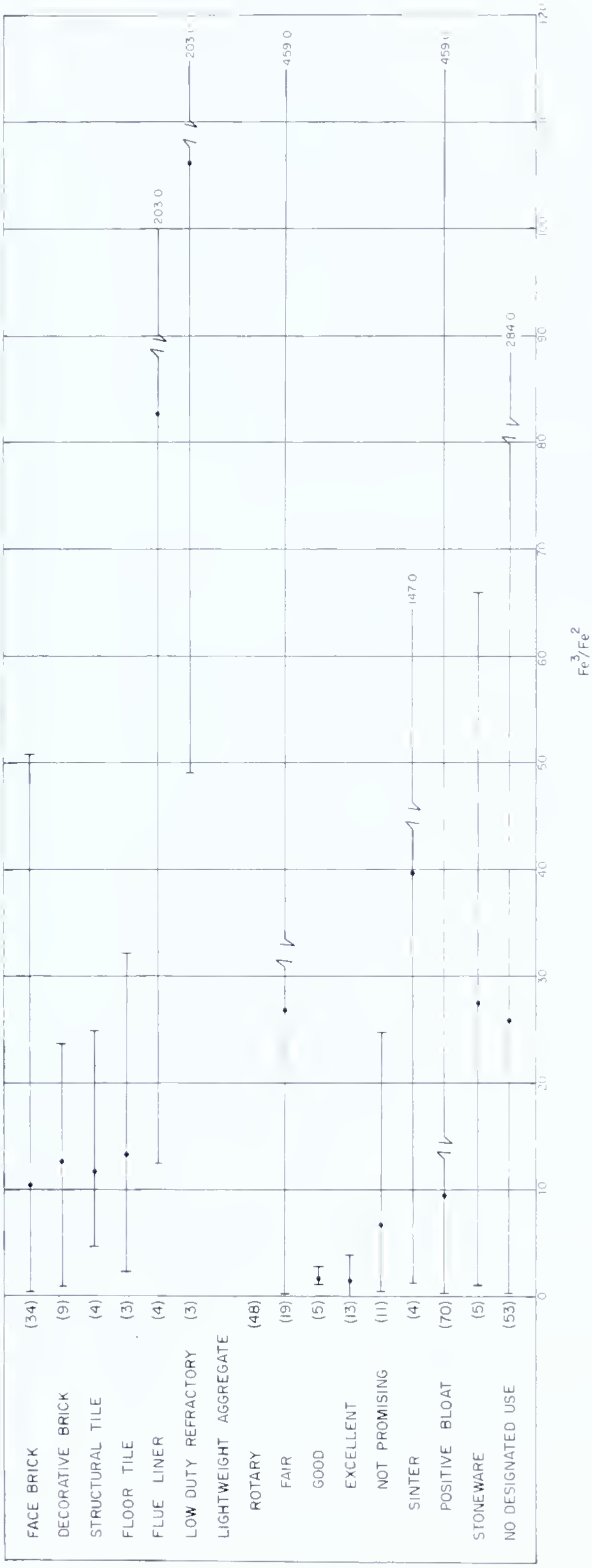


Figure 15. Fe^3/Fe^2 versus use.

Table 8. *Validity of Component Ranges for Specific Use Classifications.*

LIGHTWEIGHT AGGREGATE

COMPONENTS	ROTARY KILN																			
	Fair					*Good*					*Excellent*					*Not Promising*				
	sh	sl	sch	ls-dol	met-ig	sh	sl	sch	ls-dol	met-ig	sh	sl	sch	ls-dol	met-ig	sh	sl	sch	ls-dol	met-ig
QUARTZ	-62 +1	-1	-2 +4	+1	-2	-88 +3	-8	-2 +4	+3	-2	-1 +10	0	-1 +6	+4	0	-2 +14	0	-1 +6	+4	0
MICA	+8	0	+2	0	+1	-7 +26	-2	+2	-1	-1 +1	-12	-5	+1	-1	-2	+5	0	+2	0	0
KAOLINITE	7	1	0	0	2	8	5	0	1	2	-37 1	0	0	0	-1 +1	4	1	0	0	2
CHLORITE-VERMICULITE-MONTMORILLONITE	9	0	• •	1	1	38	2	• •	1	1	27	1	• •	1	1	9	0	• •	1	1
FELDSPAR	+33	0	0	0	0	+33	0	0	0	0	+19	0	0	0	0	-17 +1	-1	0	-2	-1
CO_2	59	5	0	0	0	54	5	0	0	0	51	5	0	0	0	-12 +13	-2	-2	0	-1
pH	-3 +3	+2	0	-3	0	-3 +41	+6	0	-3	0	-9 +32	+3	-5	-4	-1	-43 +3	+2	-8	-5	-4

COMPONENTS	SINTER					POSITIVE BLOAT					STONEWARE				
	sh	sl	sch	ls-dol	met-ig	sh	sl	sch	ls-dol	met-ig	sh	sl	sch	ls-dol	met-ig
QUARTZ	-4 +21	-1	-1 +4	+3	-2	-62 +3	0	-1 +4	+3	0	-95 +1	-10	-2 +4	+1	-3
MICA	-12 +39	-5 +1	+2	-1	-2 +1	0	0	+1	0	0	-12 +63	-5 +1	+6	-1	-2 +1
KAOLINITE	62	11	0	4	2	4	1	0	0	2	-84 +18	-1 +11	-1	-1 +1	-1 +2
CHLORITE-VERMICULITE-MONTMORILLONITE	1	0	• •	0	0	9	0	• •	1	1	1	0	0	0	0
FELDSPAR	-17 +3	-1	0	-2	-1	+1	-1	0	0	-1	+53	+1	0	0	0
CO_2	49	9	0	0	0	3	0	0	0	0	+57	-13	0	+2	0
pH	-6 +41	+6	-3	-4	0	-3 +3	+2	0	-3	0	+33	-74	0	+2	0

	STRUCTURAL CLAY PRODUCTS																				REFRACTORIES									
	Face Brick					*Decorative Brick*					*Structural Tile*					*Floor Tile*					*Low Duty Refractories*					*Flue Liner*				
COMPONENTS	sh	sl	sch	ls-dol	met-ig	sh	sl	sch	ls-dol	met-ig	sh	sl	sch	ls-dol	met-ig	sh	sl	sch	ls-dol	met-ig	sh	sl	sch	ls-dol	met-ig	sh	sl	sch	ls-dol	met-ig
QUARTZ	−12	0	−1 +2	+1	0	− 9 + 7	0	−1 +6	+4	0	−42	0	−2	0	−2	−42 +39	+ 5	−2 +6	+5	−2 +1	−29 + 1	0	−1 +4	+1	0	−29	0	−1	0	0
MICA	− 5 + 5	−2	+2	−1	0	−27 +37	−7	+2	−2	−2 +1	+37	0	+2	0	+1	−77 + 3	−11	−4 +1	−5	−2	− 5 +95	− 2 + 4	−3 +2	−1 +2	+1	+95	+ 4	+2	+2	+1
KAOLINITE	1	0	0	0	1	9	7	0	1	2	35	11	0	2	2	45	11	0	4	2	−55	− 1	−1 0		−1	−55	− 1	−1	0	−1
CHLORITE-VERMICULITE-MONTMORILLONITE	1	0	• •	0	0	9	0	• •	1	1	4	0	• •	0	1	3	0	• •	0	1	1.04	0	• •	0	1	1.04	0	• •	0	1
FELDSPAR	0	0	0	0	0	+13	0	0	0	0	+62	+ 2	+1	0	0	+62	+ 2	+1	0	0	+62	+ 2	+1	0	0	+62	+ 2	+1	0	0
CO_2	20	0	0	0	0	13	0	0	0	0	46	5	0	0	0	−12 +68	− 2 + 9	−2	0	−1	106	9	1	1	1	106	9	1	1	1
pH	0	0	0	0	0	−27 +11	+2	0	−2	0	− 2 +19	+ 2	0	−2	0	+12	+12	+2	+1	+4	− 1 +88	+12	0	0	+1	− 1 +88	+12	0	0	+1

SYMBOLS

- Sh = shale
- Sl = slate
- Sch = schist
- ls-dol = limestone-dolomite residual clay
- met-ig = meta-igneous rock residual clay

KEY:

- + = Component exceeds use range by stated number of samples.
- − = Component is less than use range by stated number of samples
- 0 = Component lies within use range
- no sign = Component exceeds by stated number of samples the use range, the lower limit of which is 0 percent.
- • = Given component not present

sion of confidence for all rock types for which a potential use has been shown to exist. A zero in any box indicates that there were no samples of that rock type for which a given component was outside the use range, e.g. the quartz contents for all samples of slate found suitable for excellent lightweight aggregate were within the defined range limits. "NS" indicates that a given component (C) was not present in the specified rock type for which a specific use had been designated. A positive number means that that number of samples exceeded the defined component range; a negative number designates the number of samples which fell below the component range. A number (other than zero) without a sign designates that number of samples which exceeded the given limits of a range for which the low limit is 0 percent. Under "sinter aggregate", opposite the mica component, the numbers —12 and +39 appear under shale, indicating twelve shale samples fell below and 39 exceeded the defined mica usability range. Such numbers imply high confidence in the limited range. In general, therefore, a zero means that the component limits for a particular use and rock type have not been established. The higher the number, the more samples there are which bracket the range, and hence a greater degree of confidence can be placed upon the range for that particular binary correlation.

It is important to emphasize that although Table 8 presents the theoretical validity of two-component correlations, given component ranges may be correct despite the fact that few or no samples lie outside that range (i.e., a zero in Table 8). Such a case must be considered because the interdependence table assumes that component (C) ranges are controlled by more than one factor, whereas in reality many of these variables may indeed be independent insofar as potential use is concerned. Quartz content, for example, in lightweight aggregate may be more important than whether the quartz is present in a shale or in a slate. Such a situation may exist in the case of the category of brick where the numbers are low or zero. Such figures would at first seem to indicate that the range limits are ill-defined. However, into this category fall a major portion of the analyzed samples. Under such circumstances confidence should be high. Other reasons for the low number of samples falling outside the range limits may be either because a rock type has the same limited range of mineralogy as does the use category into which it falls, or because the use-component range has very wide range limits into which many rock types may fall. Nonetheless, the correlations presented in the succeeding graphs are considered to be indicative of compositional variation trends within a specific use category.

MINERALOGICAL CORRELATIONS

Introduction

Mineralogical composition has generally been considered to be a primary factor in determining the potential use of a particular rock type. Such composition has been difficult to assess because of the difficulty in obtaining accurate mineral quantification. Modifications have been made in an X-ray diffraction method previously described (O'Neill and others, 1965) which enable mineral quantifications to be made within relatively narrow limits of error. Earlier workers (e.g. Murray and Smith, 1958; Searle and Grimshaw, 1958; and Grim, 1962) have shown that mineralogy influences potential use of clays and shales in several ways: 1) through grain size, shape, and distribution in rock; 2) as a function of chemical composition and reactivity for components such as water, CO_2, iron (Fe), and the alkalis; and 3) by the thermal behavior of the minerals. Properties such as fusion temperature, vitrification range, color of the fired product, bloatability, strength, and surface textures, are all a function of the minerals present even though modified by other factors. It is not the purpose of this report to evaluate all the possible mineralogical combinations which may play a part in determining a specific use, but rather to present selected empirical correlations which may be discriminatory in determining potential use.

Because of the small number of samples collected of certain rock types, the reliability of the mineralogical correlations is limited. At this stage of investigation there are insufficient samples to delineate any lateral or vertical mineral variations in any one unit, except on a gross scale. A mineralogic comparison has been made of the Martinsburg Formation using data collected for this report supplemented by previously published data (op. cit.).

Mineralogy of the Martinsburg Formation—a Comparison

The Martinsburg Formation has been the most extensively sampled formation for this clay-shale program. Average mineral composition and compositional range of Martinsburg samples has been compared in a series of histograms (Figure 9) for each mineral component. Such a comparison is made to determine what, if any, changes have occurred as a result of 1) more extensive representation of the formation, and 2) modifications of the analytical techniques. In making mineralogical comparisons, 90 samples from the Martinsburg Formation were used: 22 shales and 4 slates from the earlier investigation (O'Neill and others, 1965) and 52 shales and 12 slates from the present investigation.

Only minor differences are evident in the abundance of mica and feldspar except for a slight upward shift (about 1 percent) of the feld-

spar maximum in the samples analyzed in the present report (Figure 9). There is also a slight expansion in the feldspar range which probably is attributable to more extensive sampling. Kaolinite shows a shift in range and maximum among data from the two reports. In the present report, the range has been extended about 15 percent at the high end, and shortened about 3 percent at the low end, with a concomitant increase in the average percent kaolinite. Chlorite-vermiculite-montmorillonite shows little change, although the maximum increased and the range increased about 6 percent (Figure 9).

The quartz component expanded in range and exhibits about a 6 percent shift toward the low end of the apparently tri-modal distribution. This distribution is wider than the entire range previously reported.

Some of the changes, especially in the expansion of the range, may be attributed to the increased number of samples. Other causes of change may be related to 1) the changes in analytical technique, using standard composition curves which are somewhat different from those used in the earlier investigation; 2) lateral facies variation; and 3) changes in stratigraphic horizon.

Use Correlations

Mineral composition ranges and averages are plotted against use in Figure 11. The total number of samples for each specific use is noted in parenthesis following the use category. Uses for which there are insufficient data, such as filler, pigment, etc., have been omitted from consideration. A mineral range is generally of more practical value than a specific or average percent because of the latitude of variation that can be tolerated for a raw material within a given use category. Brick, related structural clay products, and structural tile have a fairly wide range for most mineral components, although a similar product such as floor tile has considerably more limited mineral composition ranges. Refractory products, excluding flue liner, are even more restricted in range for all minerals except kaolinite (O'Neill and others, 1965). Flue liner, although classed as a low duty-type refractory, exhibits wider ranges for quartz (Figure 11). Rotary kiln lightweight aggregate is characterized by restricted mineral ranges for all components. Detailed variation in mineralogy, which, along with rock type, is perhaps the most useful criterion for helping to pre-determine potential use, is discussed in detail below (See also O'Neill and others, 1965).

Brick

Combined face and decorative brick have a somewhat wider range for all five components than the similar use designation of structural tile, although the component averages are nearly identical. Quartz and mica have a tendency to be present in a ratio of 3:4, respectively. In the previous report (op. cit.) the ratio was closer to 1:1. A minimum amount of 15 to 20 percent quartz may prevent excess shrinkage. A maximum of

about 17 percent chlorite-vermiculite-montmorillonite (combined) may be tolerated with lesser amounts being preferable. Kaolinite does not exceed 35 percent in face brick, which is slightly higher than was found previously (op. cit.), and does not exceed 20 percent in decorative brick, because greater amounts tend to increase the refractoriness beyond economical firing temperatures. The range of mica tolerated in acceptable brick is somewhat greater than previously reported, 14 to 65 percent as compared to 33 to 53 percent (op. cit.).

Tile

Structural tile has a mineralogical composition similar to that of brick, but, for the few samples plotted here, a slightly more restricted range of components (except for quartz). Mica, kaolinite, and chlorite-vermiculite-montmorillonite (combined) all have considerably smaller component ranges, although the average composition is nearly identical to that of brick as noted by O'Neill and others (1965). The number of samples is too small to base any conclusion about either structural or floor tile in this report; structural tile was listed only by the U. S. Bureau of Mines Norris, Tennessee, Laboratory, probably accounting for the small number of samples in this use category. Perhaps the only valid conclusion is that the quartz:mica ratio is about 1:1, the same as noted previously (op. cit.).

Refractories

Only three samples were found to be suitable for potential refractory material, and all three were for low duty use. Moderately wide ranges exist for quartz and kaolinite. Mica, however, is quite restricted and exhibits about the same average (30 percent) as previously noted (O'Neill and others, 1965). Chlorite-vermiculite-Montmorillonite is absent. In comparison with previous data (op. cit.), the component ranges in this report are considerably more restricted, but, except for kaolinite, the average mineralogical composition is quite similar. These differences are considered to be a function of the fewer samples designated for refractory use in this report.

Flue Liner

Exhibits ranges and averages similar to potential low duty refractories, but quartz is slightly more abundant and kaolinite slightly less abundant. Again, the number of samples is too small to draw definite conclusions.

Lightweight Aggregate

Most of the samples for which a potential use has been designated fall into this use category. All analyzed minerals are present and because of the large number of samples involved, the range of each component is well defined, particularly for shale. Quartz content ranges from 6 percent to 50 percent. The range previously reported (op. cit.) was 25 to 48 percent. The trend of increasing quality with decreasing quartz content (see O'Neill and others, 1965) is maintained in this report.

Average quartz values are within 6 percent of those previously reported (op. cit.). Mica content has a considerably wider range, particularly in the excellent category, and an average which is 5 to 10 percent higher than previously reported. Despite an overlap in range, there is a distinct tendency for use quality to increase as mica content increases. This relationship was not apparent in the previous study (op. cit.). Kaolinite content is much the same for each of the quality grades (See O'Neill and others, 1965) and does not in any case exceed 38 percent. Clay minerals are present in all samples and the average content is the same as previously reported (op. cit.). Maximum kaolinite content for sintered aggregate does not exceed 15 to 17 percent, and 10 to 12 percent in the rotary kiln grades. Except for feldspar in potential brick raw materials, materials potentially usable for lightweight aggregate contain more feldspar than do materials for other potential uses (see also O'Neill and others, 1965). Carbonate minerals are present in nearly all samples classified as potential for lightweight aggregate use and at times reach significant proportions (> 15 percent). This suggests that at least a small amount of carbonate is necessary to produce CO_2 for bloating.

In summary, only certain aspects of mineralogical composition appear to be critical in determining a potential lightweight aggregate source material; 1) quartz content should not exceed 50 percent; 2) decreasing, or lower, quartz content favors better aggregate; 3) a minimum of 20 percent mica is required; 4) kaolinite content should not exceed about 38 percent; 5) some feldspar, chlorite-vermiculite-montmorillonite (combined), and CO_2 are beneficial to good lightweight aggregate raw material.

LITHOLOGIC CORRELATIONS

A graph showing specific use plotted against lithology is presented in Figure 12. Particular rock types have been known to be suitable for specific uses. Some shales, for example, are generally usable for brick and some tile, while others are suitable only for rotary kiln lightweight aggregate. The purpose of a lithology-use correlation is to evaluate a wide range of rocks with respect to their specific potential use.

The four major rock types have been plotted against specific use. In Figure 12 the total number of samples for each designated rock type (abscissa) and the number of samples found to have a specific use (ordinate) are given in parenthesis after each designation. The larger this latter number is, the greater is the reliability of the correlation. Along the abscissa is plotted the percent of usable samples from the total analyzed samples for a given rock type. All schist samples tested in the present study are considered to have no ceramic use. Consequently, schist is not included in Figure 12. However, some residual clays from the weathering of schists are considered to have a potential ceramic use (O'Neill and others, 1965).

The correlations illustrated in Figure 12 can be summarized as follows:

Brick

Of all the use categories, brick is the least restrictive with respect to rock type (also see O'Neill and others, 1965), with face brick being less restrictive than decorative brick. Nearly half of the clays associated with weathered limestone–dolomite rock, 31 percent of the shales, and 22 percent of the slates are suitable for brick. Although the percentages for the shales and slates are smaller than those for the residual clays of limestone and dolomite, the total number of samples is larger. The analyses indicate that the more kaolin-rich rocks have excellent potential for brick manufacture, but samples with more than 20 percent kaolinite normally have greater economic value for refractory use.

Structural Tile

Although many potential tile materials are mineralogically similar to potential brick-making material, tests suggest only slate and residual clays from limestone and dolomite are well suited for structural tile manufacture. In comparison with previous studies (O'Neill and others, 1965) significantly fewer shales were designated suitable for tile in this report. Only a few shale samples (1.5%) were designated as having any potential for tile. In spite of this, most samples suitable for brick are probably potentially suitable for some type of structural tile. Limestone–dolomite residual clays, and to some extent slate, are best suited for tiles. Neither shales nor residual clays from the meta-igneous rocks showed any tile potential. Many differences in rock type-use correlation between this report and the previous one (op. cit.) probably are the result of changes in the reporting of uses by the U. S. Bureau of Mines.

Floor Tile (Quarry Tile)

Any significant analysis of potential with respect to rock type is inconclusive due to lack of a sufficient number of samples (3) regarded as usable for manufacture of floor tile. All samples in this report designated as potential floor tile material by the U. S. Bureau of Mines were shale.

Refractories and Flue Liner

Low duty refractories and flue liner can be made from residual, kaolin-rich clays associated with limestone, dolomite, and metamorphic rocks. Of the limestone-dolomite residual clay samples, 40 percent were suitable for low duty refractories (compared with no samples in the previous report, op. cit.) and 60 percent were suitable for flue liner. About 9 percent of the residual clays associated with meta-igneous rock were suitable for both low duty refractories and flue liner. No samples analyzed in this report were designated as potential intermediate-, high-, or super-duty refractory raw material.

Lightweight Aggregate

The present and previous (O'Neill and others, 1965) investigations suggest that only slate and shale are potential sources of lightweight aggregate raw materials. Only 48 of 129 shale samples were found to be even possible potential sources for rotary kiln lightweight aggregate. Of these 48, only 18 were designated as potentially good or excellent. Four samples were determined as being suitable for sintered lightweight aggregate, a category no longer used by the U. S. Bureau of Mines, since all lightweight aggregate materials can be used for sintered aggregate. Positive bloat tests on an additional 15 samples indicated they may be potential sources for lightweight aggregate, but further testing is required to properly evaluate the sample potential. All 70 samples which had positive bloating characteristics, whether more extensively tested or not, are included on the graph. One-third of the slate samples were rated as having a fair potential for rotary kiln lightweight aggregate, but none were found to have good or excellent potential. In the case of both shale and slate, compared to previous results (op. cit.) fewer samples were found to have any potential for lightweight aggregate. The percentage potential utility of slate is greater than for shale, although no slates were as highly rated. This result is contrary to the data plotted in the previous report where only the quick fire test data were plotted. In the present report, rotary kiln evaluations were used. Apparently the slates sampled are less satisfactory than shale under bulk rotary kiln testing conditions.

Residual clays from limestone and dolomite proved positive in bloating tests for lightweight aggregate, but were not tested further by the U. S. Bureau of Mines. No other rock types were designated as potential sources of either rotary kiln or sintered lightweight aggregate.

Except for the metamorphic rocks, slate, and schist, the exclusion of rock types from a specific use category can be explained primarily on the basis of mineral content and certain specific chemical elements; secondarily by physical properties such as pH and water of plasticity (see succeeding discussions). In the case of the metamorphic rocks, grain size and rock texture can be expected to be significant controlling factors. The homogeneity and excellent cleavage of slate and to a degree some well-indurated shales, probably enhances their value as a source of expandable rotary kiln lightweight aggregate. The large grain size and the presence of interlocking grains in schist, probably inhibit a low fusion temperature.

In general there is a fair degree of correlation between rock type and specific use. Shale is not suitable for flue liner or refractories, but, along with slate, is the chief source for lightweight aggregate. Residual clays, where the clay mineral content exceeds 20 to 25 percent, are generally unsuitable for lightweight aggregate, but are potential sources of brick,

tile, and refractories. Although the percentage utility of a rock type for a specific use is generally less for the present samples than noted previously (O'Neill and others, 1965), the same uses require the same rock types. To a large extent the difference in limiting percentages between the two reports is the result of different test procedures and different evaluation judgments.

CHEMICAL CORRELATIONS

General Statement

Most of the samples collected in this study and subjected to ceramic, X-ray, and analytical chemical investigations are shales. Attempts have been made to correlate chemical characteristics of individual samples with their potential ceramic use as evaluated by the U. S. Bureau of Mines and to present the relationships graphically. Three samples tested "promising" for other than ceramic use, but in this tabulation they have been placed in the NO DESIGNATED USE category because they failed to show any promise for ceramic use. Two of the samples in question could be used as filler material in insecticide and the third may have use as an additive to a ceramic clay.

Where applicable, data given here are compared with previous correlations (O'Neill and others, 1965). A direct correlation of results between the two reports is not always possible because different analytical techniques have been used and because different laboratories have taken part in the use evaluation. Other parameters that may compensate for the lack of correlations are: 1) insufficient number of samples for valid statistical comparison of ranges and averages; 2) minor mineral and/or chemical component ratios not reported here may change the physico-chemical balance and exert a major influence on the ceramic end product; 3) re-evaluation of use and quality criteria between the previous study and the present study, especially for lightweight aggregate.

For some use categories (floor tile, flue liner, low duty refractory, and sintered aggregate) only three to five samples have been designated as having potential for that particular use. Even though these have been included in the plots, they do not represent an adequate statistical sampling to establish boundaries and their use for resource evaluation studies should be interpreted with care. Secondly, some of the designated uses for individual samples have been assigned with reservations as noted on the individual data sheets. Typical examples of these are samples No. 205-5-3 and No. 205-5-4, Monroe County, which have been suggested as doubtful for flue liner, low duty refractory, and stoneware use. In the interest of completeness, such samples have been used in the accompanying plots.

Carbon Dioxide

Most of the available carbon dioxide in a ceramic raw material is derived from carbonate minerals (calcite, dolomite, ankerite, and siderite) but some may be derived from the decomposition of organic matter (coal and petroliferous materials).

The dissociation of carbon dioxide from carbonates occurs at about 800°C and is either evolved or entrapped as a gas in vesicles within the ceramic body. Fossil carbon is frequently more abundant in ceramic raw materials than inorganic carbon. Generally it is vaporized and does not enter into the physico-chemical reactions. However, with a sufficient supply of oxygen, the solid carbon burns to carbon dioxide, and the hydrocarbons to carbon dioxide and water. If the supply of oxygen is restricted, the carbon in the various compounds is oxidized only to carbon monoxide, a powerful reducing agent which acts on ferric oxide and possibly manganese oxide to produce carbon dioxide. The reactions are:

$Fe_2O_3 + CO$ 200° Δ – 1000°C $2FeO + CO_2$
$3Fe_2O_3 + CO$ 200° Δ – 1000°C $2Fe_3O + 4CO_2$
$MnO_2 + CO$ 200° Δ – 1000°C $Mo + CO_2$

The carbon held in carbonates decomposes between 600° and 800°C to yield CO_2 as follows:

$FeCO_3$ 600° Δ 800°C $FeO + CO$
$CaCO_3$ 600° Δ 800°C $CaO + CO_2$

Liberated carbon dioxide may cause bloating. New compounds formed in a reducing environment may act as fluxes, reacting with silica to form silicates that may cause the ceramic body to deform. Carbon dioxide may affect the fired ceramic body by decreasing its specific gravity and increasing its porosity. Most structural clay products and refractories require rather dense fired bodies. An excess of carbon dioxide adversely influences a raw material for many uses.

It will be noted from a review of Figure 13 that for samples included in this present study the average percent carbon dioxide that is tolerable for any ceramic use is less than two percent; secondly, the carbon dioxide range for ceramic products, such as structural tile, floor tile, and flue liner, requiring dense bodies is also less than two percent. Only for those ceramic products in which low specific gravity is desirable (lightweight aggregate, for example) or can be tolerated (certain types of face and decorative brick) does the carbon dioxide range exceed two percent. In all cases, the carbon dioxide range is considerably less than the range of "No Designated Use" samples, indicating a probable restrictive effect. For the present study it may be tentatively concluded that the maximum tolerable percentage of carbon dioxide for ceramic raw materials is less than 8.3 percent, but may possibly be as high as 11.6 as reported by O'Neill and others (1965, Figure 15, page 427). However, in the pre-

vious study (op. cit.) the average for the fair, good, and excellent lightweight aggregate categories is somewhat above two percent carbon dioxide, as contrasted with less than two percent in this report. In both studies, the averages and ranges are greater for the fair and excellent quality lightweight aggregate than for good quality lightweight aggregate.

K/Na Ratio

Potassium and sodium are associated with alumino-silicates, composing the major fraction of the alkalies of a ceramic raw material. The major alkali-bearing silicates are feldspar, muscovite or illite, and biotite. Illitic mica normally is the major alkali-bearing constituent in most ceramic raw materials. Muscovite contains a maximum of 11.8 percent stoichiometric K_2O, a small part of which is usually replaced by soda. Illitic micas may contain as little as 6 percent K_2O. The potash feldspars (orthoclase and microline) contain about 16.9 percent stoichiometric K_2O. Albite, oligoclase, leucite, and hornblende are the major soda-containing minerals that occur in ceramic raw materials; however, they are seldom present in any significant amount with the result that their influence as fluxing agents is negligible.

The chief effect of alkali-bearing minerals in ceramic raw materials is to reduce the vitrification temperature or refractoriness by combining with alumina and silica to form liquid. The liquid, which forms on firing of clays containing alkalies, does not crystallize readily on cooling, but forms a glass, which behaves as though it were a super-cooled liquid. Because of the readiness of liquid formation, alkalies impart imperviousness and strength to the fired clay bodies.

According to Clarke (1924, page 631, Table, Column B), the average shale contains 3.25 percent K_2O and 1.31 percent Na_2O for a K/Na ratio of 2.81. For other lithologies, Clarke found the average ratio to be considerably lower. Vinogradov (1962) reported an average K/Na of 2.45 for shale, and Horn and Adams (1966) report a ratio of 5.13. The discrepancies are largely in Na_2O content. In the present study (Figure 14) the average K/Na ratio for many use categories is higher than these average ratios. In fact, individual K/Na ratios for samples in some use categories range as high as 87.0 for floor tile and 342.5 for face brick. Such ratios so distort the ranges and averages that additional data will have to be complied before valid range boundaries can be established for the various use categories.

For some use categories, such as refractories, in which refractoriness is a definitive criterion, the average K/Na ratio is higher than for uses in which a fluxing action is desirable (lightweight aggregates, for example). In most such samples a high K/Na ratio indicates a high mica/feldspar ratio. Mica breaks down, or "fluxes", at a higher temperature than feldspar, and thus can be detrimental in refractories and lightweight aggregate source material.

The ratio ranges and averages are higher than previously reported because of an occasionally very low Na_2O content, rather than high K_2O (or mica). As previously noted (O'Neill and others, 1965), "excellent" lightweight aggregate tends to have a higher average K/Na than "good" and "fair" lightweight aggregate categories.

Ferric/Ferrous (Fe^3/Fe^2) Ratio

Iron occurs in two oxidation states: the divalent or ferrous form and the trivalent or ferric form. The oxidation state of an argillaceous material is roughly related to the ratio of ferric to ferrous iron (Fe^3/Fe^2). This ratio is also an indicator of the weathering state of the sedimentary materials because weathering oxidizes the rock and changes ferrous iron to ferric iron. Divalent iron links the chains of silicon-oxygen tetrahedra in minerals; trivalent iron may replace aluminum in silicate minerals. Iron is common also as oxides and sulfides in sedimentary rocks. Iron weathered out of minerals is not long retained in solution, but is redeposited as oxides or hydroxides.

Chemical analyses of some samples in this study indicate Fe^2 to be so low that for some use categories the Fe^3/Fe^2 ratios range above 200 and one as high as 459 ("Lightweight Aggregate-Fair"). The field description for the sample with Fe^3/Fe^2 ratio of 459 states the sampled material was slightly to severely weathered. Such a ratio is atypical of unweathered ceramic raw material. In this study the chemical analyses for four samples are reported to have an FeO content of less than 0.001 percent (or iron reported as "Not Detected") and eight samples in which the ferric to ferrous ratio is greater than 50. At least in part these high ratios are the result of extreme weathering. There may also have been an oxidation of some ferrous to ferric iron during analytical chemical procedures.

The Fe^3/Fe^2 ranges and averages illustrated in Figure 15 are not directly applicable to fired products. In refractories, oxidation of ferrous (Fe^2) to ferric (Fe^3) iron may render the product more refractory (Searle and Grimshaw, 1958, p. 658). In lightweight aggregate, Fe^3 may aid in the formation of gases necessary for bloating (Conley and others, 1948; Riley, 1951; Ehlers, 1958) and in the formation of a glassy phase. However, the extent and character of oxidation during firing is dependent upon variables other than the initial oxidation state of the raw material. For example, air circulation, available H_2O, carbonaceous content, and firing temperature all play a role in oxidation. At best, the Fe^3/Fe^2 ratio of the raw material gives some indication of the potential for iron oxidation or reduction in the sample, and thus also indicates the potential for influencing such dried characteristics as color, shrinkage, bloatability, and refractoriness. Because of these complexities in the

oxidation process, limits of Fe^3/Fe^2 content (Figure 15) are not yet well defined for most specific uses.

A comparison of the previous Fe^3/Fe^2 averages (O'Neill and others, 1965, Figure 18, page 432) with those of the present study illustrates similarity for the lightweight aggregate grades, providing the sample responsible for the plotted point of 459 is eliminated from the compilation for "fair" lightweight aggregate. If this is done, the range for "Fair" lightweight aggregate becomes 3.34 to 20.21 and averages 3.34. "Good" and "Excellent" lightweight aggregate appear to tolerate a lower Fe^3/Fe^2 ratio than "Fair" quality raw material. In the case of face brick, both the range and average are higher in the present study. The previously reported data for structural tile (op. cit.) have a wider range but a lower average than for the present study. For the NO DESIGNATED USE category, the range in the present study is twice that previously reported, but the average, which is of greater significance, is approximately the same.

Total Iron (Fe)

The total percent of iron in each sample was recalculated from the percent ferric and ferrous oxide as determined by wet chemical methods.

In the present study, correlation between total iron and use (Figure 16) is not definitive for most use categories. In some instances this is the result of an insufficient number of samples with a given use. The average amount of iron for most ceramic use categories reported fall roughly half-way (4.2 to 6.4 percent) between the minimum (about 0.5 percent) and the maximum (nearly 11.0 percent). These values are essentially the Same as the average and range for total iron in the NO DESIGNATED USE category (average 4.75 percent, range 1.50-11.00 percent). There appear to be limits to the amount of iron in raw materials used for decorative brick, floor tile, flue liner, and refractories. However, this correlation may be a matter of insufficient number of samples tested, human interpretation, and currently desirable fired color, resulting in an apparent limitation rather than a tolerance factor for iron. In the previous study (O'Neill and others, 1965) the tolerance for iron in decorative brick was reported to be quite restrictive, with a lower percentage range. The present study suggests a reasonably restrictive range, but the average and range are similar to the average and range for most uses. Floor tile is similar to decorative brick; that is, the average and range for total iron fall within the range for most ceramic uses.

High iron clays often have iron-bearing mineral assemblages that lower the refractoriness of the clay. Flue liners and refractories are particularly dependent upon the refractory properties of the raw materials

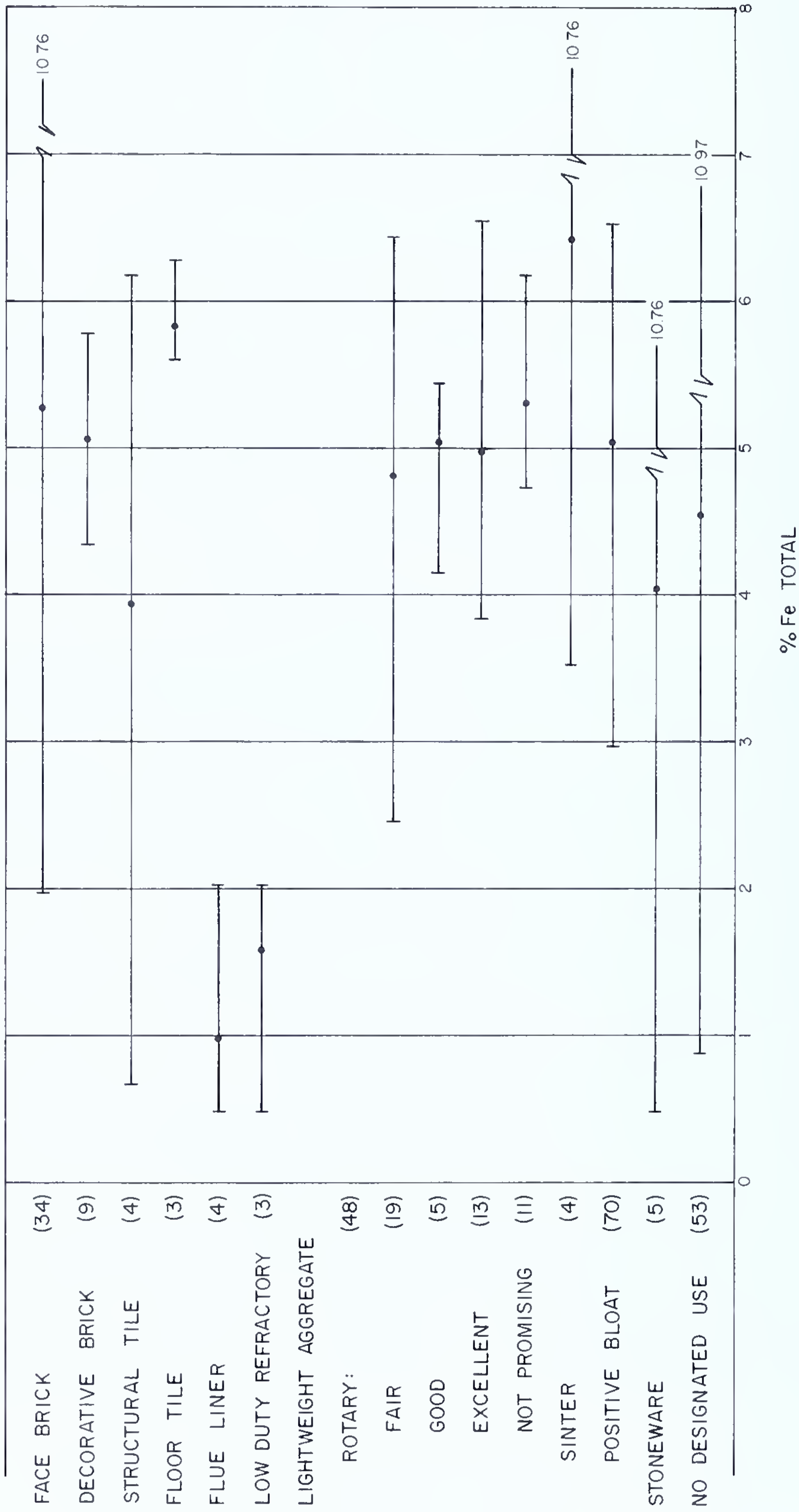


Figure 16. Total Fe versus use.

and in the present study only materials with low total iron were judged to be suitable. Commercially, fireclays or refractory clays are commonly regarded as gray or buff burning. It is suggested, but not necessarily true, that raw materials in this study, testing as potentially useful for floor tile, may also have the requisite refractory properties for flue liner or low duty refractory use.

As noted previously (O'Neill and others, 1965, Figure 17), there is apparently a minimal amount of total iron that is required in lightweight aggregate (about 4.5 percent). The minimal total iron indicated by the present report is about 4.0 percent. The average value for both reports is between 5.0 and 5.5 percent, and the upper range preferably is less than 7.0 percent.

The ability of total iron to be used as a restrictive criterion is somewhat modified by the ferric/ferrous ratio (see ferric/ferrous iron ratio discussion), but is of primary importance. Oxidation changes during firing alter the original Fe^3/Fe^2 ratio and may result in a dark colored fired product that may be undesirable. Iron content may also increase the fluxing action (formation of low-temperature iron silicates), affect vesiculation and glass formation, and influence specific gravity.

Conclusions

The relationships noted between chemical composition and use are empirical. Mineral abundance, composition and textures affect all chemical reactions. As a consequence, the utility of a raw material is not solely dependent upon chemical composition even though a direct correlation between use and chemistry is illustrated by graphical plots. However, many of the foregoing chemical components are significant and restrictive.

In themselves, without recourse to other variables, the K/Na ratios indicate a more restricted tolerance for flue liner and refractories than for brick and floor tile; average lightweight aggregate ratios are about 5.0 and also show a somewhat restricted range. As noted previously (O'Neill and others, 1965), a minimal total iron content is required for lightweight aggregate (between 4.0 and 4.5 percent) and a maximum range of about 7 percent exists for these samples as well as for those previously studied (op. cit.). Largely because of the absence of refractory grade raw materials in this study, the Fe^3/Fe^2 ratio is less significant than other chemical variables, but it is important in controlling the fired color along with total iron. The carbon dioxide (CO_2) contents show that a certain amount is beneficial to lightweight aggregate, with about two percent as the average, and perhaps optimum, amount. For good and excellent lightweight aggregate, carbon dioxide is restricted to less than eight percent in both studies.

PHYSICAL PROPERTIES CORRELATIONS: PH, WATER OF PLASTICITY, AND DRYING SHRINKAGE

Water of plasticity and drying shrinkage are test characteristics that only secondarily control raw material potential because they are functions of primary variables such as mineralogy, physical properties, and rock type. They are, nonetheless, considered important because they have a direct influence on the structural strength and shape of clay–shale raw materials and products. pH is controlled by mineralogy, particle size, and weathering characteristics, and likewise is a secondary, rather than primary, factor in use potential. These three factors have been correlated with use and rock type (Figure 17) for samples studied in this report (see also O'Neill and others, 1965). The ranges of these factors are quite broad and consequently are limited in their utility as a determinant in arriving at an evaluation of potential use.

Of the three factors chosen for correlation with rock type, pH appears to be the most sensitive. Correlation with rock type shows that nearly neutral pH is characteristic of shales and residual clays of meta-igneous rocks. Schist-pyrophyllite and limestone-dolomite residual clays are slightly acidic (Figure 17). Water of plasticity indicates that with increasing amounts of clay minerals, the water of plasticity (i.e. the water that must be added for the clay to become plastic) decreases. The broad range of the schist-pyrophyllite category results from the very high percent water of plasticity (35%-46%) for pyrophyllite, which in turn extends the upper range and average for the composite category. Drying shrinkage appears to have little significant correlation with rock type. These data are similar to those data published previously (O'Neill and others, 1965).

Correlation of pH with use (Figure 17) indicates that similar use categories have similar pH values that are relatable to rock type. Material suitable for brick and structural tile, for example, is more alkaline (7.6 average) than floor tile, low duty refractories and flue liner samples. Likewise, brick and structural tile materials were found to have a greater potential from shale and hence exhibit a similar pH. In the same manner refractory materials have a greater potential from the more acidic limestone-dolomite residual clays (5.75 average pH) and are similar to previously published results on a greater number of samples (op. cit.).

No significant use correlations are indicated by either water of plasticity or drying shrinkage. Potential use categories that include samples with greater amounts of clay minerals have lower percentages of water of plasticity. As noted previously (op. cit.) the range of water of plasticity decreases with increasing quality of potential lightweight aggregate samples and might be used to exclude some shales.

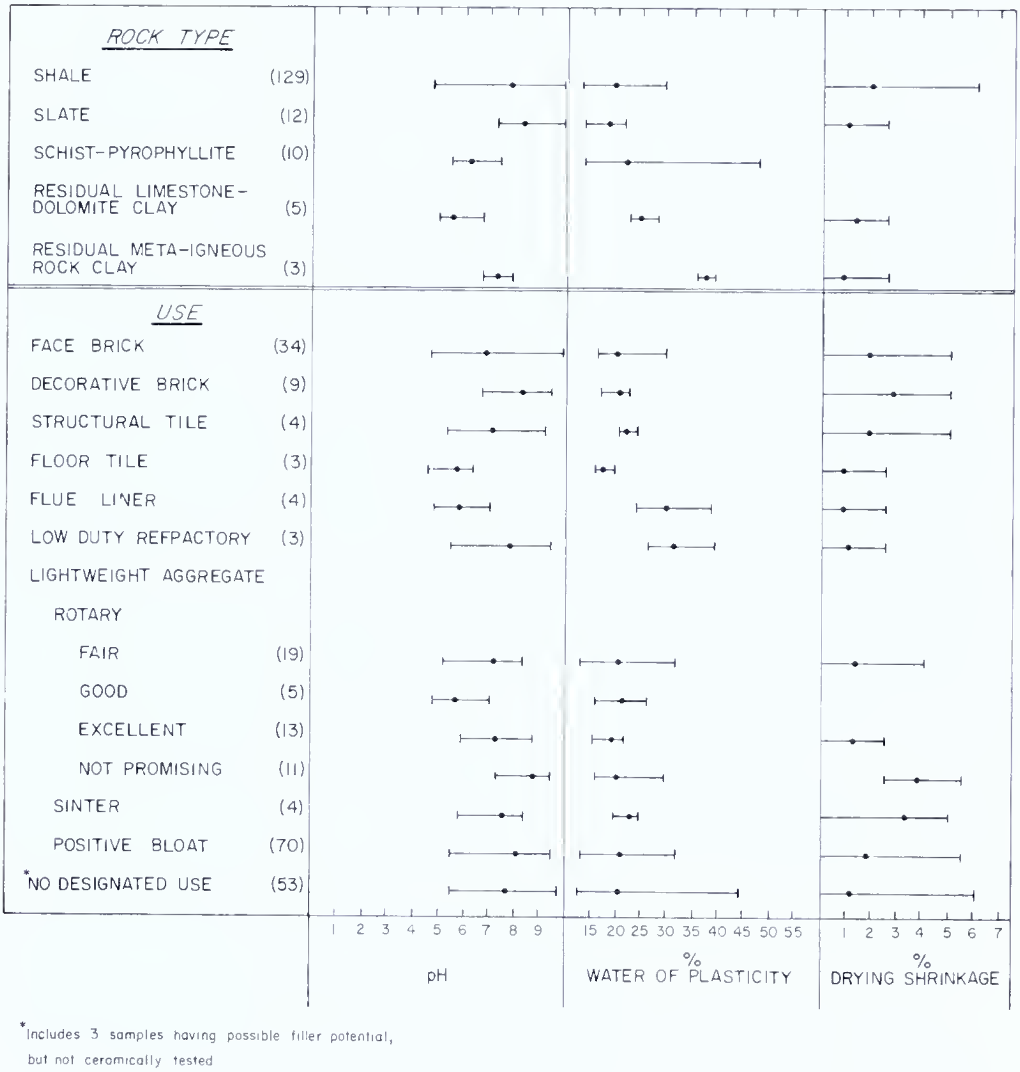


Figure 17. Rock type and potential use versus pH, water of plasticity, and drying shrinkage.

SUMMARY

In this investigation many of the types of correlations reported in the preceding clay-shale resource publication (O'Neill and others, 1965) were used in the interest of continuity of the research program and to provide additional sample data for comparative studies. The correlations and conclusions reported apply only to the data presented in this publication and may require modification as new laboratory information become available.

In the ceramic evaluation studies a majority of the samples were assigned the use with the highest economic potential. As a consequence,

some samples will have an additional potential use where less demanding ceramic properties are required. However, correlation studies were limited to using the categories assigned by the ceramic testing laboratories, which, of course, tends to arbitrarily restrict correlation limits. Secondly, a high percentage of the total number of samples tested are shales so that relationships between use and other lithologies cannot be adequately determined.

Specific factors that help to define a specific use are discussed in preceding sections of this, and the previous (O'Neill and others, 1965) report. As a general rule, rock type is the foremost factor to be considered. However, because shales are the chief source for manufacture of bricks, tiles and lightweight aggregate, other exclusion variables must be applied to separate these potential uses. In decreasing order of significance, these are: mineralogy (chiefly clays, mica, and quartz), chemical composition (chiefly alkalies, CO_2, and total iron), pH, and water of plasticity.

Laboratory results suggest that there are several distinct geographic areas where geologic units show potential as raw material for brick and rotary kiln lightweight aggregate manufacture. Many of the same samples are considered to be sources of ceramic raw material for many structural clay product uses. There are four geologic units in which multiple samples were shown to have "excellent" potential for rotary lightweight aggregate use. The geologic units (from oldest to youngest) and their associated trade areas are:

Kinzer Formation	York—Harrisburg—Lancaster
Martinsburg Formation	Chambersburg—Waynesboro, Pa.—Hagerstown Md.
	York—Harrisburg—Lancaster
Mahantango Formation	Chambersburg—Waynesboro, Pa.—Hagerstown, Md.
	Reading—Pottstown
Lockatong Formation	Allentown—Bethlehem—Easton
	Philadelphia

Areas in which these formations occur have adequate raw material reserves, utilities, manpower, and transportation facilities to establish manufacturing plants for producing rotary kiln lightweight aggregate and structural clay products such as face brick for markets in southeastern Pennsylvania.

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GLOSSARY

Note: See technical dictionaries for words not herein defined.

Absorption The relation of the weight of water absorbed by a specimen to the weight of the dry specimen, expressed in percent.

Adsorption The adhesion of molecules of gases, or of ions, or of molecules in solution, to the surfaces of solid bodies with which they are in contact.

Acidic oxide; Acid oxide An oxide whose behavior at the high temperatures used in ceramics is that of an acid. (See basic oxide).

Alkali A soluble mineral salt. The alkalies more commonly present in ceramic raw materials are potash (K_2O), soda (Na_2O), and ammonia (NH_3). Alkalies are generally the most powerful fluxing material found in ceramic raw materials.

Alumina Free aluminum oxide (Al_2O_2).

A.S.T.M American Society for Testing Materials.

Argillaceous Applied to rocks or substances composed of clay, or having a notable proportion of clay in their composition.

Basic oxide An oxide whose behavior at the high temperatures used in ceramics is that of a base.

Binary correlation Any correlation between two variables such as the range of quartz content plotted against samples potentially useful for low duty refractories.

Black coring In burning ceramic ware made from clay containing carbonaceous matter, the ware may come from the kiln having its center (core) black in color, this black coring is caused by a deficiency in the amount of air that is supplied to a kiln at the time that the ware is at a dull red heat, resulting in the reduction of iron instead of oxidation.

Blistering The development during firing of enclosed or broken macroscopic vesicles, or bubbles in a body, or in a glaze or other coating.

Bloating Expansion produced by heat that causes the formation of a vesicular (cellular) structure while material is in the thermoplastic state.

Bloating range Temperature range in which a clay material will bloat.

Body ceramic The clay or other ceramic material, either natural or synthetic, constituting the main substance from which a ceramic ware is manufactured. Body is distinguished from glaze or decorations which are always placed on the outside of the body.

Bonding power Ability of a ceramic raw material to stand the addition of non-plastic matter. This property is tested by determining the relative strengths of different clays when mixed with varying proportions of sand.

Burning (firing) The heat treatment to which ceramic products are subjected during manufacture.

B. T. U. Abbreviation for Brisish Thermal Unit. A B.T.U. is the quantity of heat required to raise the temperature of one pound of water one degree F.

Calcine 1. (V.) To heat a material for the purpose of (a) expelling undesirable components, (b) reducing the firing shrinkage, or (c) fixing color in ceramic stains.

2. (N.) A material which has been prepared by calcining.

Carbonaceous Containing carbon, as wood or other vegetable matter does; may be present in ceramic raw material as coal, asphalt, graphite, wood fibers, etc.

Cement A common term for refractory mortar; also portland cement.

Ceramic(s) A broad term which includes all products made from earthy materials by the application of heat.

Channel sample A sample collected continuously along a relatively long distance but narrow width (oriented normal to bedding in this program).

Chemically combined water That combined chemically as part of the molecule.

Clay (1) A natural material with plastic properties; (2) an essential composition of particles of very fine size grades; (3) an essential composition of crystaline fragments of mineral that are essentially hydrous aluminum silicates or occasionally hydrous magnesium silicates.

Clay minerals Used here to designate kaolinite and the collective group of chlorite-vermiculite-montmorillonite; does not include mica.

Claystone An indurated clay.

Colloidal A very finely divided substance with particles ranging between 10^{-5} and 10^{-7} cm. in diameter.

Composite sample A sample collected at uniform intervals along an outcrop, representative of each proportion of the different lithologies in the exposure.

Crazing The cracking which occurs in fired glazes or other ceramic coatings due to critical tensile stresses.

Dehydration The stage in firing of ceramic ware during which chemically combined water is driven out of the ware.

Density (1) The degree of compactness in physical structure; (2) the mass or quantity of substance in grams per cubic centimeter.

Diaspore Al_2O_3. H_2O. Common term loosely used to mean diaspore clay.

Diaspore clay "A rock consisting essentially of diaspore, bonded by fire clay."

Diffraction pattern Diffracted X-rays recorded on film or by other mechanical means, giving a means of identification of crystalline materials.

Drying Removal of uncombined water or other violatile substance from a ceramic raw material or product by evaporation, usually expedited by low-temperature heating.

Dunting Cracking of a ceramic body, particularly near the surface.

Efflorescence Refers to the discoloration that appears on the surface of clay products due to soluable salts. (See scumming).

Empirical Depending upon observation and experience without regard to theory.

Fatty Smooth and highly plastic, unctuous, at room temperature.

Fire clay A mineral aggregate, essentially hydrous silicates of aluminum, of suitable refractories for use in refractories, structural clay products, stoneware and other ceramic products.

Firing The controlled heat treatment of ceramic ware in a kiln or furnace during the process of manufacture, to develop the desired final properties.

Firing Range Range of firing temperature within which a ceramic composition develops properties which render it commercially useful.

Flint clay A flint-like clay practically devoid of natural plasticity and usually showing a fracture.

Floe rock Loose ganister, or other rock, occuring in or taken from an accumulation of rock at the base of a slope.

Fmi Fmi is the multiplier factor used to determine the X-ray line broadening of illite to correct for illite percentage error in quantitative analysis by diffracton X-ray methods.

Flux An eutectic mixture in a ceramic body which becomes liquid and takes the other substances present into solution when a certain high temperature has been reached.

Fusion A state of fluidity or flowing as a result of being heated.

Fusion point The temperature at which fusion occurs; a term often used for P.C.E.

Ganister A high silica rock (quartzite), suitable for silica refractories.

Glaze A ceramic coating matured to the glassy state on a formed ceramic article, or the material from which the coating is made.

Grab sample A sample collected randomly along an exposure or a stockpile.

Gritty Presence of coarser hard particles (grit); grittiness.

Hardness Resistance to scratching or abrasion. The brittle hardness used in mineralogy differs from the pentration hardness (ductile) used in metalurgy.

Scales: Fired—Soft: scraped by fingernail
- Fairly hard: scratched by nail
- Hard: scratched by knife
- Very hard: scratched by metal file
- Steel hard: unscratched by metal file

Moh's (an empirical scale used in mineralogy for hardness determined relative to a set of standards)—

1. Talc
2. Gypsum
3. Calcite
4. Fluorite
5. Apatite
6. Orthoclase
7. Quartz
8. Topaz
9. Corundum
10. Diamond

Illite Fine-grained muscovite mica often slightly deficient in potassium and sometimes poorly crystalline; frequently a weathering product of primary or better crystallized muscovite.

Indurated A term applied to rock hardened by heat, pressure, and cementation.

Interference, mineral Used in this report to describe the superposition of X-ray reflections from two or more minerals on an X-ray diffraction chart and rendering the differentiation of these minerals difficult.

KBR Electrical conductivity of a clay-water suspension measured with instrument called a Solu Bridge.

Kiln A furnace for firing ceramic products.

Lightweight aggregate Inert material which is a natural occuring or prepared by expanding, calcining, or sintering, used in construction composed predominately of lightweight cellular and granular material which are strong and durable whose unit weight cannot exceed 70 pounds (fine aggregate) and 55 pounds (coarse aggregate) per cubic foot.

Line broadening Used in this report to refer to the broadened peaks on X-ray reflections from a particular atomic spacing, or related group of spacings. It is a measure of degree of crystallinity and particle size.

Loss-on-Ignition (LOI) Loss in weight of moisture-free material, heated to constant weight at 900-1,000°C (1652-1832°F).

Maturing range The time-temperature range within which a ceramic body, glaze, or other composition may be fired to yield specific properties.

Mealy Granular feel caused by lumpy, soft particles.

Metamorphic rock Rock which has formed in response to pronounced changes of temperature, pressure, and chemical environment, exclusive of weathering.

Overfiring (Overburning) Heating a material to a temperature which causes expansion, bloating, and vessicular structure.

Oxidizing atmosphere One in which the oxygen is high enough to cause oxidation.

Pelitic Argillaceous.

Phyllite An argillaceous rock intermediate in metamorphic grade between slate and schist. The mica crystals impart a silky sheen to the surface of the cleavage (or schistosity).

pH Measurement of relative acidity or alkalinity.

Plasticity That property of a material that enables it to be molded into desired forms, which are retained after the pressure of molding has been released.

Porosity, apparent The relationship of the open pore space in a ceramic specimen to its bulk volume, expressed in percent.

Possible potential A sample of questionable potential utility.

Preferred orientation Used in this report to designate a parallelism of platy minerals which enhances certain X-ray reflections.

PSI Pounds per square inch.

Pyrometric Cone Equivalent (P.C.E.) A measure of the refractoriness of a material, expressed in terms of standard pyrometric cones. More precisely, the number of that standard pyrometric cone whose tip would touch the supporting plaque simultaneously with a cone of the refractory material being investigated.

Quick-firing Process of firing a dried sample in a muffle kiln which is at an actual firing temperature and keeping the sample in the kiln to soak for 15 minutes.

Rational analysis (chemical) Chemical analysis method used to determine the mineral composition of a ceramic raw material directly.

Refractoriness The capacity of a material to resist fusion or vitrification at high temperatures. In ceramics, the property of resistance to melting, softening or deformation at high temperatures. For fire-clay materials the most commonly used index of refractoriness is that known as the P.C.E.

Residual clay Clay found in the same location as the rock from which it was formed.

Restrictive correlation A correlation between two or more variables which is significant because it is limited in the following ways:

(a) by a narrow range whose lmits are well defined.

(b) by a range which differs considerably from other ranges for the same variable in a binary correlation.

Rotary kiln An inclined tubular furnace which rotates on its axis. (Note: The material to be heated is fed into the elevated end and passes to the lower and discharge end where the heat is introduced).

Rotary-kiln aggregate Expanded aggregate made in a rotary kiln.

Schist 1) A medium or coarse-grained metamorphic rock with sub-parallel orientation of the micaceous minerals which dominate its composition.
2) Rock which has a foliated structure, split up in thin, irregular plates, not by regular cleavage as in clay slate, nor in large flat laminae, as in flagstone.

Scumming Formation of undesirable coating on surface of fired ceramic material. (See Efflorescence).

Shale A thinly stratified, consolidated, sedimentary argillaceous rock with well-marked cleavage parallel to bedding.

Shrinkage A volume reduction of a ceramic material during air-drying or firing.

Siliceous clay Clay sized particles high in quartz, not lithified.

Sinter A ceramic material or mixture fired to less than complete fusion, resulting in a coherent mass, or the process involved.

Sintered aggregate Expanded or porous aggregate made by sintering.

Slaking Disintegration of air dried clay under the action of water.

Slate A fine-grained metamorphic rock possessing a well-developed fissility (slaty cleavage).

Slow firing Process of firing dried samples in a muffle kiln started from room temperature and raised to maximum temperature in several hours and removing a sample at each predetermined temperature.

Soak A conditioning of ceramic ware to a uniform temperature.

Soft mud Ceramic material of the soft consistency used for hand-molded ware.

Soluble salts Compounds formed by the combining of acids and bases.

Specific gravity The ratio of the weight of a unit volume of a substance to the weight of an equal volume of water. True specific gravity is based on the volume of the solid material, excluding all pores. Bulk specific gravity (BSG) is based on the volume as a whole; i.e., the solid material with all included pores. Apparent specific gravity (ASG) is based on the volume of the solid material plus volume of the sealed pores.

Stiff mud A plastic mix of clay with a very stiff consistency, as extruded from an auger machine.

Stoichiometric formula composition The ideal chemical composition of a substance according to its formula composition.

Strength Ability to withstand handling. Same as dry or green strength.

Structural clay products Products made chiefly of clay which are used by the building trades and in non-residential construction.

Temper To mix with water (as clay) and knead to a uniform texture.

Till Nonsorted, nonstratified sediment carried or deposited by a glacier.

Triaxial diagram (Triangular diagram) An equilatereal triangle used to represent graphically the relationships of all possible combintions of three components.

Tunnel kiln A long tunnel-shaped furnace through which ceramic ware is moved on cars, passing progressively through zones in which temperature is maintained for preheating, burning, and cooling.

Ultimate analysis (Chemical) The elementary composition of a substance.

Underclay A stratum of claystone beneath a coal bed often containing roots of coal plants, especially Stigmaria; includes flint clay. Also called "seat rock."

Vitrification The process of changing a substantial part of a ceramic body into a glassy substance at high temperatures; the second stage of fusion in which the clay partices are soft enough to close up all pore spaces so that further shrinkage is impossible.

Vitrification range The maturing of a vitreous ceramic body.

Warpage The deviation from the intended or normal surface of a ceramic shape resulting from bending or bowing during manufacture.

Water of plasticity Percentage of water added to dry clay to plasticize a clay material; Atterberg test.

Weathering The mechanical and chemical processes in which a rock is changed when exposed to the agents of the weather that the rock bears little resemblance to the original rock.

Workability Ability to be worked or formed by hand, tested mainly by plasticity.

X-ray analysis The identification of crystalline materials by use of X-rays.

INDEX

Note: See glossary for definitions used in text. For more definitive explanations see technical dictionaries.

TABLE 6. Chemical Analyses and Physical Properties of Shale and Clay Samples

County & Sample No.	Lithology (Fm.)	L.O.I.	H_2O Loss @ 110°C	Combined H_2O	SiO_2	Al_2O_3	Fe_2O_3	FeO	CaO	MgO	CO_2	Na_2O	K_2O	TiO_2	P_2O_5	MnO	S (Total)	C (organic - fixed)	Total	PH	Water of Plasticity	Unfired Properties: Dry Shrinkage %	Dry Strength	Drying Character	Working Character	Quick-firing Test
Adams																										
128-9-2	Precambrian Schist	1.77	NA	NA	72.42	13.03	3.53	0.89	NA	0.64	0.32	1.31	5.04	0.37	NA	NA	NA	NA	99.32	5.80	14.8	0.0	Low	Satisf	Non-Plast.	Neg.
129-2-6	Precambrian Schist	4.20	NA	NA	41.40	28.35	13.39	0.23	NA	0.21	0.05	0.17	9.78	0.50	NA	NA	NA	NA	98.18	6.00	13.5	0.0	Low	Satisf	Non-Plast.	Neg.
129-3-7	Precambrian Schist	1.20	NA	NA	83.77	8.51	2.10	0.43	NA	0.11	0.05	0.04	3.24	0.10	NA	NA	NA	NA	99.55	5.50	18.0	0.0	Low	Satisf	L. Plast.	Neg.
129-3-8	Precambrian Schist	2.15	NA	NA	75.28	11.15	4.17	0.35	NA	0.59	<0.01	0.11	5.27	0.31	NA	NA	NA	NA	99.39	5.70	18.8	0.0	Low	Satisf	L. Plast.	Neg.
129-7-3	Precambrian Schist	1.72	NA	NA	74.13	11.80	2.77	1.24	NA	1.65	0.40	0.89	4.67	0.38	NA	NA	NA	NA	99.65	5.70	18.8	0.0	Low	Satisf	L. Plast.	Neg.
129-7-4	Precambrian Schist	1.65	NA	NA	75.42	11.63	2.80	0.98	NA	1.19	0.14	0.90	4.27	0.35	NA	NA	NA	NA	99.33	6.50	18.6	0.0	Low	Satisf	L. Plast.	Neg.
129-7-5	Precambrian Schist	2.74	0.26	2.04	67.08	17.13	5.35	0.07	0.30	1.79	0.06	0.03	4.65	0.32	NA	NA	None	0.11		6.70	18.8	0.0	Low	Satisf	L. Plast.	Neg.
138-7-3A	Precambrian Pyrophyllite	5.01	0.55	NA	77.00	12.00	2.49	0.01	<0.05	0.30	0.11	0.85	1.90	0.24	NA	NA	0.02	0.09		5.80	34.6	0.0	Fair	Fair	Short working	Neg.
138-7-3B	Precambrian Pyrophyllite	4.85	0.15	NA	51.50	34.70	1.19	0.05	0.11	0.22	0.07	1.73	4.80	0.81	NA	NA	0.04	0.14		7.45	47.6	0.0	Good	Fair	Plastic	Neg.
138-7-5	Precambrian Schist	NA	NA	NA	80.76	9.00	2.46	1.64	NA	0.50	<0.01	0.07	3.71	0.14	NA	NA	NA	NA	99.50	5.80	14.0	0.0	Low	Satisf	Non-Plast.	Neg.
139-1-5A	Gettysburg	NA	NA	3.08	50.05	17.70	4.95	1.07	5.65	2.75	5.49	3.76	2.75	0.86	NA	NA	>0.09	0.09	98.37	9.35	23.6	4.5	Good	Fair Scum	Short	Pos.
139-1-5B	Gettysburg	NA	NA	4.24	48.18	17.70	5.89	1.44	4.46	3.51	4.36	3.24	3.73	0.90	NA	NA	>0.54	0.10	98.29	9.25	23.0	5.0	Good	Fair	Short	Pos.
139-1-5C	Gettysburg	NA	NA	3.29	50.39	17.38	7.06	0.58	3.75	2.72	3.32	5.24	3.46	0.83	NA	NA	<0.02	0.07	98.11	9.40	20.0	3.0	Good	Good	Short	Pos.
139-1-5D	Gettysburg	NA	NA	3.84	48.55	17.47	3.75	3.52	3.04	4.46	4.59	5.04	3.11	0.83	NA	NA	<0.90	0.08	99.18	9.30	17.0	2.0	Fair	Fair Scum	Short	Pos.
139-1-5E	Gettysburg	NA	NA	3.77	50.47	18.07	6.21	0.95	4.17	3.10	3.94	3.64	3.70	0.83	NA	NA	<0.04	0.10	98.99	9.30	22.0	3.0	Good	Good Scum	Short	Pos.
139-4-6	Gettysburg	NA	NA	3.47	60.80	15.92	6.41	0.32	1.12	2.66	0.84	4.31	2.38	0.86	NA	NA	<0.02	0.06	99.16	9.30	22.0	3.0	Good	Good Scum	Short	Neg.
139-4-7A	Gettysburg	6.43	0.78	3.67	52.90	17.96	7.78	1.30	2.62	3.44	1.66	3.30	2.78	0.78	NA	NA	None	0.49		8.80	19.7	2.5	Low	Satisf	L. Plast.	Neg.
139-4-7B	Gettysburg	NA	NA	4.42	52.27	18.44	5.79	1.78	1.85	2.78	1.74	4.07	4.28	0.78	NA	NA	<0.02	0.08	98.29	9.25	16.5	3.0	Fair	Fair Scum	Short	Pos.
139-5-12A	Gettysburg	NA	NA	6.27	55.61	18.80	8.29	0.65	0.97	2.63	0.21	1.39	3.11	0.98	NA	NA	<0.01	0.02	98.94	8.00	24.0	5.0	Good	Good	Plastic	Pos.
139-5-12B	Gettysburg	NA	NA	4.95	50.27	16.42	6.68	1.17	5.82	2.87	4.51	1.05	3.07	0.98	NA	NA	<0.01	0.12	97.92	9.00	21.0	5.0	Good	Fair	Short	Neg.
139-5-12C	Gettysburg	NA	NA	4.49	53.95	16.77	8.48	0.32	2.69	2.67	1.95	1.47	3.81	0.98	NA	NA	<0.01	0.05	97.64	9.20	21.0	5.0	Good	Good	Short	Neg.
139-7-8	Gettysburg	NA	NA	4.04	54.14	17.06	7.79	0.30	3.33	3.30	2.35	2.45	3.14	1.00	NA	NA	<0.01	0.07	98.98	9.30	21.0	5.0	Fair	Fair Scum	Short	Pos.
139-10-10	Gettysburg	NA	NA	4.09	57.61	17.09	5.89	0.29	1.72	2.81	1.42	3.50	3.10	0.90	NA	NA	<0.01	0.09	98.52	9.30	21.0	4.5	Good	Good Scum	Short	Pos.
139-10-11	Gettysburg	NA	NA	3.89	56.10	16.70	6.55	0.12	3.21	2.90	2.37	1.33	3.01	0.87	NA	NA	<0.01	0.09	97.15	9.15	21.0	4.0	Good	Fair Scum	Short	Neg.
Berks																										
176-8-7	Martinsburg Shale	5.61	0.31	3.54	61.56	15.44	5.40	0.58	1.81	4.38	1.85	0.68	2.76	0.90	NA	NA	None	0.22		7.90	15.9	2.5	Low	Satisf	L. Plast.	Neg.
177-2-3	Martinsburg Shale	5.84	0.51	NA	63.60	15.30	6.63	1.03	0.46	1.14	0.26	1.18	3.70	0.97	NA	NA	0.07	0.12		7.60	24.0	4.0	Good	Fair	Short working	Pos.
177-2-4	Martinsburg Shale	5.13	0.23	NA	69.60	8.70	6.80	2.20	1.00	2.00	0.81	1.18	2.70	0.59	NA	NA	0.03	0.13		8.95	19.0	1.0	Good	Fair	Short working	Pos.
177-5-5	Hershey	4.98	1.18	4.86	66.50	17.52	3.44	0.65	0.17	1.39	0.02	0.68	2.99	0.99	0.07	0.04	0.00	0.18		5.30	22.8	2.5	Fair	Satisf	L. Plast.	Neg.
186-5-3	Martinsburg Shale	5.11	0.91	NA	67.50	13.10	7.61	0.59	0.35	1.58	0.23	0.44	2.90	0.78	NA	NA	>0.01	0.02		6.95	20.8	0.0	Good	Good	Short	Neg.
186-5-6	Martinsburg Shale	7.39	0.18	NA	67.90	6.60	3.09	2.57	6.95	1.34	3.82	1.33	2.20	0.53	NA	NA	<0.02	0.69		8.30	17.0	0.0	Poor	Fair	Short	Pos.
186-7-10	Martinsburg Shale	5.37	0.58	5.92	59.10	18.74	4.94	2.81	0.10	2.58	0.10	0.52	3.72	0.82	NA	NA	None	0.42		6.70	16.0	2.5	Low	Satisf	L. Plast.	Neg.
186-9-9	Martinsburg Shale	4.67	0.56	5.04	60.26	18.77	4.57	2.38	0.40	2.40	0.20	1.03	3.20	0.86	NA	NA	None	0.29		7.80	16.0	2.5	Low	Satisf	L. Plast.	Neg.
188-1-3	Brunswick	3.83	1.24	NA	71.00	12.40	6.19	0.27	0.42	0.98	0.15	0.62	3.38	0.86	NA	NA	>0.03	0.14		7.90	19.8	2.5	Good	Good Scum	Plastic	Neg.
188-2-2	Stockton	3.57	1.23	NA	70.30	13.00	6.20	0.40	0.12	1.04	0.29	0.62	3.80	0.93	NA	NA	>0.02	0.14		6.70	21.2	2.5	Good	Good Scum	Plastic	Neg.
197-7-2	Brunswick	NA	NA	4.49	53.95	16.77	8.48	0.32	2.69	2.67	1.95	1.47	3.81	0.98	NA	NA	<0.01	0.05	97.64	9.40	22.0	2.0	Good	Good	Short	Pos.
Bucks																										
216-8-1	Brunswick	6.24	0.25	2.20	54.56	17.49	5.59	1.15	3.53	3.07	4.00	2.62	3.12	0.80	NA	NA	None	0.05		6.70	16.7	0.0	Low	Satisf	L. Plast.	Neg.
216-9-2	Brunswick	3.19	0.37	2.83	59.78	19.49	3.20	4.39	0.76	2.11	0.36	2.30	3.05	0.85	NA	NA	None	0.00		8.00	21.2	2.5	Low	Satisf	L. Plast.	Neg.
217-2-4	Lockatong	4.15	0.17	NA	61.90	13.30	3.89	3.99	1.92	2.02	1.10	4.66	3.00	0.78	NA	NA	<0.06	0.35		8.00	21.0	2.0	Fair	Fair	Short	Pos.
217-2-4A	Brunswick	3.04	0.22	NA	64.50	13.25	6.51	1.13	0.15	1.70	0.58	4.77	4.10	0.75	NA	NA	>0.03	0.19		8.30	20.0	3.0	Fair	Fair	Short	Neg.
217-2-4B	Lockatong	4.12	0.41	NA	63.40	14.20	4.21	3.51	0.08	2.83	ND	1.98	4.95	0.68	NA	NA	<0.06	0.21		7.90	21.0	5.0	Fair	Good	Short	Pos.

TABLE 6. Chemical Analyses and Physical Properties of Shale and Clay Samples (continued)

[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	MgO	[illegible]	Na_2O	K_2O	TiO_2	P_2O_5	MnO	S (Total)	C (organic fixed)	Total	pH	Unfired Properties: Water of Plasticity	Dry Shrinkage %	Dry Strength	Drying Character	Working Character	Quick-firing Test
[illegible]	[illegible]	[illegible]				[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	0.56	0.62	2.10	0.69	NA	NA	None	0.03		6.80	20.5	0.0	Low	Satisf	L. Plast.	Neg.
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	3.16	0.91	0.20	2.02	0.35	1.21	2.23	1.06	NA	NA	None	0.08		8.20	15.8	2.5	Low	Satisf	L. Plast.	Neg.
[illegible]	[illegible]	[illegible]		[illegible]	[illegible]	[illegible]	2.76	1.90	1.11	2.69	0.62	0.89	2.50	0.70	NA	NA	None	0.33		6.20	17.6	2.5	Low	Scum	L. Plast.	Pos.
[illegible]													none									None				
Franklin																										
[illegible]	Martinsburg	[illegible]		[illegible]	[illegible]	8.30	3.80	2.88	1.51	1.70	0.14	0.68	2.50	0.62	NA	NA	0.02	0.12		7.00	16.9	2.5	Low	Satisf	L. Plast.	Pos.
[illegible]	Martinsburg	[illegible]	[illegible]	[illegible]	[illegible]	16.77	3.35	3.67	1.92	1.94	0.58	0.94	2.40	0.99	NA	NA	0.17	0.50		7.00	15.9	0.0	Low	Satisf	L. Plast.	Pos.
[illegible]	[illegible] Shale	[illegible]	[illegible]	1.30	46.82	9.33	1.29	1.51	19.15	1.06	13.82	0.51	1.54	0.44	NA	NA	0.11	1.01		7.00	16.1	0.0	Low	Satisf	L. Plast.	Neg.
[illegible]	[illegible] Shale	[illegible]	[illegible]	1.66	63.40	17.57	3.65	1.30	1.51	1.88	0.35	0.59	3.16	0.84	NA	NA	0.08	0.35		6.20	19.7	2.5	Fair	Satisf	L. Plast.	Neg.
[illegible]	[illegible] Shale	[illegible]	[illegible]	[illegible]	31.62	6.48	1.51	0.65	31.05	1.34	23.62	0.05	1.20	0.33	NA	NA	0.12	0.69		7.40	12.5	0.0	Low	Satisf	Non-Plastic	Neg.
[illegible]	Martinsburg Shale	[illegible]	0.58	4.37	62.38	14.85	4.22	2.88	3.23	2.54	1.45	1.40	2.21	0.77	NA	NA	0.04	0.56		6.80	16.2	2.5	Low	Satisf	L. Plast.	Neg.
[illegible]	Martinsburg Shale	[illegible]	1.24	1.36	60.53	17.21	4.71	1.94	1.02	2.63	0.26	0.94	2.88	0.96	NA	NA	0.12	0.07		6.40	14.9	2.5	Low	Satisf	Non-Plastic	Pos.
109-6-5	Martinsburg Shale	1.86	0.38	4.34	61.30	17.48	4.61	2.63	1.21	3.05	0.20	1.00	2.54	0.91	NA	NA	0.04	0.09		6.40	15.9	2.5	Low	Satisf	L. Plast.	Neg.
109-6-7	Martinsburg Shale	5.11	0.93	5.72	59.08	18.62	5.15	2.23	1.61	2.89	0.31	1.00	2.88	0.95	NA	NA	0.06	0.28		7.8	18.8	2.5	Low	Satisf	L. Plast.	Pos.
109-9-6	Martinsburg Shale	[illegible]	1.26	4.39	62.06	16.27	3.96	2.45	1.61	2.95	0.10	1.08	2.40	0.95	NA	NA	0.07	0.49		6.40	17.2	2.5	Low	Satisf	L. Plast.	Pos.
109-9-8	Martinsburg Shale	5.98	0.95	5.75	61.04	17.77	4.28	1.87	1.11	2.55	0.20	0.68	3.16	0.91	NA	NA	0.10	0.44		5.20	20.4	2.5	Low	Satisf	L. Plast.	Neg.
118-8-1	Martinsburg Shale	5.05	0.26	NA	69.60	10.00	4.94	2.49	0.70	1.66	0.99	1.80	2.80	0.86	NA	NA	0.05	0.35		7.80	25.4	0.0	Good	Good	Short working	Pos.
[illegible]	Martinsburg Shale	4.78	0.14	NA	68.40	11.00	3.24	4.44	1.42	1.72	1.21	1.26	2.80	0.82	NA	NA	0.55	0.33		8.30	25.5	0.0	Good	Good	Short working	Pos.
[illegible]	Martinsburg Shale	4.54	0.74	4.71	63.06	15.67	2.80	4.54	1.21	2.68	0.54	1.32	2.21	0.83	NA	NA	0.11	0.70		6.90	16.1	2.5	Low	Satisf	L. Plast.	Pos.
[illegible]	Martinsburg Shale	5.20	0.70	6.00	63.62	15.96	4.86	1.73	0.71	2.43	0.28	1.00	2.64	0.82	NA	NA	0.02	0.33		6.50	16.4	2.5	Low	Satisf	L. Plast.	Neg.
119-4-1	Martinsburg Shale	5.24	0.51	NA	69.00	11.60	6.36	1.07	0.32	1.58	0.37	0.95	3.00	0.80	NA	NA	>0.04	0.35		7.30	28.0	4.5	Good	Good	Plastic	Pos.
119-4-7	Martinsburg Shale	4.85	0.74	5.71	61.48	15.77	4.22	3.74	0.50	3.02	0.14	1.43	2.64	0.86	NA	NA	0.07	0.47		6.40	15.4	0.0	Low	Satisf	L. Plast.	Pos.
119-4-8	Martinsburg Shale	9.82	0.38	3.82	51.48	17.51	1.18	5.62	6.65	2.71	5.48	0.92	2.64	0.75	NA	NA	0.04	0.54		7.40	12.7	0.0	Low	Satisf	Non-Plastic	Pos.
119-7-2	Martinsburg Shale	5.44	0.16	NA	66.00	12.00	3.99	3.47	1.99	1.39	1.36	1.65	3.20	0.85	NA	NA	0.75	0.54		8.30	23.8	0.0	Good	Good	Plastic	Pos.
119-7-3	Martinsburg Shale	5.22	0.12	NA	64.10	14.00	3.34	4.09	1.95	1.46	1.54	1.58	3.30	0.83	NA	NA	0.97	0.43		8.40	14.4	2.0	Poor	Fair	Short Working	Pos.
119-7-6	Martinsburg Shale	5.48	0.77	4.73	58.14	19.74	5.54	2.27	0.40	2.34	0.45	0.92	3.31	0.44	NA	NA	0.07	0.44		6.00	16.5	0.0	Low	Satisf	L. Plast.	Pos.
Lancaster																										
168-3-8A	Cocalico	3.35	0.21	NA	68.20	13.30	6.03	1.00	0.17	1.42	0.26	1.65	3.98	0.88	NA	NA	>0.02	0.11		7.75	31.8	1.0	Good	Fair	Short	Pos.
168-3-8B	Cocalico	5.56	0.09	NA	64.30	11.10	4.74	1.62	5.40	1.52	4.47	1.33	3.60	0.77	NA	NA	0.26	0.32		9.45	24.8	1.0	Good	Fair	Short	Pos.
168-4-10A	Cocalico	5.64	0.26	3.94	62.94	15.51	2.11	2.59	3.83	2.22	0.75	1.40	2.04	1.11	NA	NA	None	0.74		7.30	17.5	0.0	Low	Satisf	L. Plast.	Neg.
168-4-10B	Cocalico	8.59	0.14	2.91	53.88	16.58	1.59	3.53	7.26	2.82	6.25	1.21	2.40	1.09	NA	NA	0.61	0.30		7.40	17.2	2.5	Low	Satisf	L. Plast.	Neg.
168-5-9	Cocalico	5.99	0.44	5.26	56.52	21.57	5.96	1.22	0.20	2.54	0.45	0.27	3.36	1.16	NA	NA	None	0.12		6.30	22.6	2.5	Low	Satisf	L. Plast.	Neg.
168-8-11	Kinzers	4.33	0.33	4.27	54.16	23.18	3.86	2.81	0.06	2.11	0.00	0.08	8.52	0.81	0.19	0.01	0.02	0.30		6.00	15.4	0.0	Low	Satisf	L. Plast.	Pos.
168-8-12	Kinzers	3.96	0.38	3.78	54.84	22.22	4.56	2.52	0.06	2.05	0.00	0.07	8.34	0.81	0.15	0.03	0.02	0.33		6.60	15.1	0.0	Low	Satisf	L. Plast.	Pos.
178-8-5	Kinzers	7.03	0.18	6.82	54.68	22.54	4.25	1.26	0.03	2.31	0.00	0.10	6.12	0.85	0.20	0.01	0.01	0.63		5.50	21.1	0.0	Low	Satisf	L. Plast.	Pos.
Lebanon																										
157-3-5	Mahantango	4.13	0.38	NA	75.80	10.00	4.33	0.76	0.31	0.76	0.55	0.46	2.30	1.06	NA	NA	<0.04	0.26		6.65	19.0	0.5	Good	Fair	Short working	Neg.
167-1-5	Martinsburg Shale	5.22	0.40	NA	66.60	12.50	6.42	0.45	1.80	1.88	1.91	0.71	3.50	0.86	NA	NA	>0.03	0.09		7.40	16.0	1.0	Fair	Poor	Short working	Pos.
167-1-6	Martinsburg Shale	5.19	0.80	NA	65.60	14.70	7.60	0.42	0.38	0.99	0.59	0.44	3.70	0.92	NA	NA	<0.03	0.14		6.00	20.0	0.0	Fair	Fair	Short working	Pos.
167-1-7	Martinsburg Shale	4.80	0.86	4.94	56.54	21.80	7.82	0.22	0.20	1.34	0.57	0.04	4.20	1.27	NA	NA	None	0.02		6.30	19.6	2.5	Low	Satisf	L. Plast.	Neg.
Lehigh																										
186-3-7	Martinsburg Slate	8.78	0.37	3.83	55.36	17.05	0.37	3.96	6.05	2.86	4.59	1.03	2.40	0.72	NA	NA	0.61	0.47		7.50	18.5	2.5	Low	Satisf	L. Plast.	Pos.
186-5-8	Martinsburg Slate	7.05	0.20	4.65	59.30	17.53	0.03	4.46	4.03	2.33	3.08	1.03	2.64	0.73	NA	NA	0.40	0.58		9.00	20.3	2.5	Low	Satisf	L. Plast.	Pos.
186-6-4	Martinsburg Slate	3.91	0.30	NA	73.35	9.60	5.29	1.62	0.47	1.43	ND	1.06	2.50	0.73	NA	NA	>0.01	0.07		7.30	21.0	0.0	Fair	Good	Short	Pos.
186-6-5	Martinsburg Shale	5.20	0.73	NA	64.40	15.40	7.09	1.21	0.40	1.39	ND	0.70	3.20	0.92	NA	NA	>0.01	0.22		7.30	20.6	0.0	Good	Good	Short	Neg.

TABLE 6. Chemical Analyses and Physical Properties of Shale and Clay Samples (continued)

County & Sample No.	Lithology (Fm.)	L.O.I.	H_2O Loss @ 110°C	Combined H_2O	SiO_2	Al_2O_3	Fe_2O_3	FeO	CaO	MgO	CO_2	Na_2O	K_2O	TiO_2	P_2O_5	MnO	S (Total)	C (organic - fixed)	Total	pH	Unfired Properties: Water of Plasticity	Dry Shrinkage %	Dry Strength	Drying Character	Working Character	Quick-firing Test
BUCKS (Cont.)																										
217-2-4C	Lockatong	5.83	0.31	NA	62.60	13.50	4.26	1.74	1.60	1.69	1.62	4.27	3.80	0.69	NA	NA	0.12	1.85		7.40	22.0	5.0	Good	Good	Short	Pos.
217-2-5	Brunswick	3.30	0.28	NA	62.30	14.00	7.80	0.64	1.24	2.04	0.51	3.70	4.20	0.77	NA	NA	>0.01	0.14		8.20	22.0	5.0	Fair	Good	Short	Neg.
217-2-5A	Brunswick	4.89	0.22	NA	60.80	13.45	7.52	0.68	2.70	2.20	2.70	3.70	3.20	0.76	NA	NA	0.02	0.17		8.30	21.0	1.0	Good	Good	Short	Neg.
217-3-3	Brunswick	NA	NA	3.32	50.71	18.74	8.54	0.12	1.91	3.40	2.22	4.81	4.20	0.90	NA	NA	0.01	0.02	98.90	8.95	22.0	5.0	Good	Good	Short	Neg.
217-3-8	Lockatong	7.12	0.33	3.42	46.38	19.44	0.93	6.91	2.42	4.34	3.58	5.50	3.72	0.77	NA	NA	None	0.07		8.70	18.2	2.5	Low	Satisf	L. Plast.	Pos.
217-3-9	Lockatong	7.34	0.20	4.45	44.70	18.77	2.03	6.70	2.62	3.78	2.66	5.50	3.79	0.86	NA	NA	None	0.30		7.60	18.5	0.0	Low	Satisf	L. Plast.	Pos.
217-6-1	Lockatong	2.73	0.09	NA	63.60	13.90	6.25	0.87	2.71	1.55	0.88	3.90	3.65	0.75	NA	NA	<0.01	0.19		8.72	22.0	6.0	Good	Fair Scum	Short	Neg.
217-6-1A	Lockatong	1.72	0.08	NA	66.10	14.20	6.74	0.96	0.42	1.37	ND	3.65	4.00	0.82	NA	NA	<0.01	0.03		8.35	23.0	5.0	Good	Fair Scum	Short	Pos.
217-6-2	Lockatong	4.19	0.04	NA	60.10	12.40	2.45	4.28	5.76	3.00	2.52	2.12	5.00	0.60	NA	NA	>0.01	0.22		8.81	19.0	4.0	Good	Good Scum	Short	Pos.
217-6-10	Stockton	4.01	0.15	2.95	54.00	19.72	6.48	1.08	1.61	2.36	0.93	4.21	2.93	0.85	NA	NA	None	0.03		7.50	25.8	0.0	Low	Satisf	L. Plast.	Neg.
217-7-1	Lockatong	6.15	0.20	3.35	51.32	18.58	2.02	5.47	3.23	3.01	3.24	3.85	3.51	0.82	NA	NA	0.27	0.60		7.60	23.7	0.0	Low	Satisf	L. Plast.	Pos.
217-8-6	Lockatong	8.78	0.22	2.58	50.90	16.09	0.96	4.32	6.25	3.86	6.10	3.88	3.72	0.77	NA	NA	0.10	0.38		8.30	23.6	0.0	Low	Satisf	L. Plast.	Neg.
217-8-7	Lockatong	9.18	0.21	3.04	46.34	18.05	0.00	6.34	5.14	4.85	5.90	3.89	3.72	0.73	NA	NA	0.66	0.82		8.00	19.4	0.0	Low	Satisf	L. Plast.	Pos.
217-9-11	Lockatong	6.70	0.27	1.89	53.28	17.14	3.56	3.13	4.28	2.41	4.83	5.18	3.18	0.85	0.19	0.10	0.00	0.30		8.70	14.3	0.0	Low	Satisf	L. Plast.	Neg.
217-9-12	Lockatong	11.09	0.17	3.04	44.20	15.99	2.00	4.91	8.12	3.77	8.31	4.86	3.68	0.65	0.18	0.14	0.49	0.52		8.00	21.3	0.0	Low	Satisf	L. Plast.	Pos.
227-8-1	Lockatong	6.65	0.76	6.52	58.64	24.77	2.10	0.71	0.00	0.79	0.00	0.23	3.68	1.29	0.06	0.07	0.00	0.15		8.80	12.7	0.0	Low	Satisf	L. Plast.	Pos.
Chester																										
188-8-4	Precambrian Anorthosite	10.58	2.30	10.10	42.54	22.87	15.14	0.50	0.50	1.93	0.35	0.52	0.55	2.46	NA	NA	None	0.87		6.60	35.6	2.5	Low	Satisf	L. Plast.	Neg.
198-6-1A	Lockatong	NA	NA	3.71	54.70	18.38	7.03	0.17	2.37	2.33	2.01	3.53	4.91	0.83	NA	NA	<0.02	0.08	100.07	9.30	22.0	4.0	Good	Fair	Short	Pos.
198-6-1B	Lockatong	NA	NA	2.42	53.88	17.64	7.51	0.14	2.91	2.31	3.88	5.23	3.38	0.87	NA	NA	<0.01	0.09	100.27	9.90	22.0	4.0	Good	Good	Short	Pos.
199-7-1	Precambrian Pegmatite	9.13	0.14	NA	50.90	33.40	2.90	ND	0.08	0.40	ND	0.17	2.70	0.22	NA	NA	>0.01	0.14		7.00	38.0	0.0	Fair	Good	Short	Neg.
Cumberland																										
118-6-2	Martinsburg	5.45	0.73	5.12	61.72	17.66	4.34	2.30	1.11	2.77	0.00	0.78	2.84	0.91	NA	NA	0.03	0.52		5.90	20.3	2.5	Low	Satisf	L. Plast.	Pos.
128-1-4	Martinsburg	5.34	0.93	4.57	61.54	17.31	5.74	1.51	0.30	2.64	0.10	0.73	2.88	0.83	NA	NA	None	0.46		6.80	17.8	2.5	Low	Satisf	L. Plast.	Pos.
128-3-3	Martinsburg	5.47	0.58	4.17	61.32	18.51	5.23	1.87	0.20	2.61	0.20	0.68	3.16	0.82	NA	NA	0.02	0.49		5.80	18.6	0.0	Low	Satisf	L. Plast.	Pos.
137-8-3A	Martinsburg	5.84	0.56	NA	64.80	12.30	2.63	4.77	1.60	1.85	2.02	1.58	3.68	0.88	NA	NA	0.14	0.24		9.10	13.8	0.0	Fair	Fair Scum	Short	Pos.
137-8-3B	Martinsburg	5.15	0.59	NA	66.90	12.50	3.99	3.47	0.44	1.73	0.15	0.86	3.95	0.94	NA	NA	0.02	0.31		8.65	22.4	4.0	Good	Good	Plastic	Pos.
137-9-2	Martinsburg	4.71	1.00	NA	64.50	15.50	5.69	1.94	0.28	0.93	0.13	1.65	3.77	0.94	NA	NA	>0.03	0.09		7.60	20.0	NA	Good	Fair	Short	Neg.
137-9-4	Martinsburg	6.25	1.34	4.21	55.16	20.22	7.57	1.30	0.40	1.73	0.06	0.68	2.84	0.85	NA	NA	0.04	0.74		4.60	16.0	0.0	Low	Satisf	L. Plast.	Neg.
138-2-6	Martinsburg	5.65	0.69	4.51	60.46	17.43	5.90	1.37	0.30	2.61	0.00	0.51	2.84	0.78	NA	NA	None	0.62		6.90	18.7	2.5	Low	Satisf	L. Plast.	Pos.
138-7-4	Precambrian Metarhyolite	2.33	0.04	NA	67.00	18.30	4.06	0.01	>0.02	0.56	0.33	0.43	6.80	0.42	NA	NA	>0.02	0.09		7.70	36.2	0.0	Fair	Fair	Plastic	Pos.
147-7-1	Martinsburg	5.15	0.53	NA	67.60	12.00	4.04	0.18	0.61	1.52	0.95	1.26	3.80	0.82	NA	NA	0.04	0.44		8.50	22.4	2.0	Good	Good	Plastic	Pos.
148-1-2	Martinsburg	4.62	1.71	NA	68.30	14.00	6.56	ND	>0.05	1.04	0.22	0.51	3.90	0.92	NA	NA	>0.02	0.12		8.00	28.6	0.0	Good	Fair	Plastic	Pos.
Dauphin																										
147-8-4	Martinsburg	9.27	0.45	3.95	54.08	16.56	3.30	1.80	8.06	2.34	5.71	0.78	2.02	0.70	NA	NA	None	0.02		9.00	21.5	2.5	Low	Scum	L. Plast.	Neg.
147-8-6	Martinsburg	5.73	0.82	4.43	58.96	18.66	4.69	2.59	0.60	2.39	0.51	1.14	2.81	0.70	NA	NA	0.18	0.53		5.90	17.9	2.5	Low	Satisf	L. Plast.	Pos.
147-8-7	Martinsburg	6.03	1.66	5.24	56.30	20.01	5.15	1.66	0.40	2.30	0.11	0.68	2.81	1.34	NA	NA	None	0.34		6.70	18.7	2.5	Low	Satisf	L. Plast.	Neg.
147-9-2	Martinsburg	5.90	0.34	5.81	55.52	22.46	8.64	0.43	0.20	0.78	0.14	0.54	3.31	0.80	NA	NA	None	0.10		6.20	25.3	0.0	Low	Satisf	L. Plast.	Neg.
147-9-3	Martinsburg	5.87	0.37	5.78	54.18	24.73	4.91	3.10	0.20	1.73	0.23	0.81	2.83	0.92	NA	NA	0.01	0.36		6.80	19.1	0.0	Low	Satisf	L. Plast.	Neg.
147-9-5	Martinsburg Shale	4.84	0.33	4.67	63.00	16.05	4.61	2.66	0.30	2.48	0.34	1.08	2.69	0.85	NA	NA	None	0.32		5.50	16.5	0.0	Low	Satisf	L. Plast.	Pos.
148-3-6	Martinsburg Shale	5.30	0.70	4.95	56.77	21.93	7.68	0.72	0.10	2.02	0.00	0.03	3.50	0.99	NA	NA	0.02	0.16		5.40	25.4	0.0	Low	Satisf	L. Plast.	Neg.
148-3-7	Martinsburg Shale	5.65	0.72	5.63	60.16	20.03	7.07	0.50	0.10	1.17	0.00	0.01	3.29	0.88	NA	NA	0.15	0.16		6.40	29.0	0.0	Low	Satisf	L. Plast.	Neg.
157-5-6	Martinsburg Shale	19.54	0.23	NA	51.30	3.00	1.70	1.13	13.90	7.16	17.77	0.46	1.07	0.29	NA	NA	0.02	0.10		9.65	17.0	1.0	Good	Fair	Short working	Neg.

TABLE 6. Chemical Analyses and [illegible] Properties of Shale and Clay Samples (continued)

[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	SiO_2	Al_2O_3	Fe_2O_3	FeO	CaO	MgO	CO_2	Na_2O	K_2O	TiO_2	P_2O_5	MnO	S (Total)	C (organic fixed)	Total	pH	Unfired Properties: Water of Plasticity	Dry Shrinkage %	Dry Strength	Drying Character	Working Character	Quick-firing Test
[illegible]	[illegible]	[illegible]	[illegible]	4.10	[illegible]	16.73	1.42	[illegible]	0.40	2.91	0.12	1.08	3.36	0.75	NA	NA	None	0.51		8.00	20.0	2.5	Low	Satisf	L. Plast.	Pos.
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	3.27	0.87	1.01	[illegible]	0.77	NA	NA	0.67	0.75		[illegible]	22.5	2.5	Low	Satisf	L. Plast.	Neg.
[illegible]																										
[illegible]	[illegible]	[illegible]	[illegible]	3.95	65.92	18.58	2.19	0.58	0.10	1.17	0.39	0.27	5.66	0.93	NA	NA	None	0.03		5.70	22.5	0.0	Low	Satisf	L. Plast.	Neg.
[illegible]	[illegible]	[illegible]	[illegible]	NA	77.40	12.30	0.91	ND	0.06	0.75	0.13	0.30	3.63	0.85	NA	NA	>0.03	0.09		4.82	27.1	0.5	Fair	Good Scum	Short	Neg.
[illegible]	[illegible]	3.22	0.16	NA	78.90	12.00	0.70	ND	0.08	0.64	0.15	0.21	3.50	0.73	NA	NA	0.04	0.14		5.05	27.9	2.5	Fair	Good	Short	Neg.
[illegible]	[illegible]	[illegible]	0.14	1.51	87.13	7.02	0.88	0.07	0.15	0.01	0.21	0.08	1.71	0.34	NA	NA	None	0.09		6.40	23.6	0.0	Low	Satisf	L. Plast.	Neg.
Montgomery																										
[illegible]	Lockatong & Brunswick	[illegible]	0.06	2.94	57.62	16.69	1.77	4.03	4.23	2.88	3.22	2.70	2.54	0.80	NA	NA	0.17	0.39		9.40	15.0	0.0	Low	Satisf	L. Plast.	Neg.
198-2-2A	Lockatong	7.06	0.06	2.59	57.04	15.29	1.36	3.74	5.85	2.72	5.36	3.13	2.50	0.82	NA	NA	0.05	0.07		9.40	15.1	2.5	Low	Satisf	L. Plast.	Neg.
198-2-2B	Lockatong	6.77	0.09	2.71	56.44	17.21	0.58	4.25	5.04	2.57	4.16	2.32	3.44	0.73	NA	NA	0.08	0.05		9.40	13.9	2.5	Low	Satisf	L. Plast.	Pos.
198-2-2C	Brunswick	5.99	0.21	2.79	56.48	16.58	4.20	2.66	3.43	2.81	3.40	3.44	2.32	0.85	NA	NA	None	0.10		9.40	13.0	2.5	Low	Satisf	L. Plast.	Pos.
207-5-3	Lockatong	1.08	0.08	1.27	52.98	19.89	1.90	6.70	2.67	4.20	0.04	4.54	4.42	0.75	NA	NA	None	0.15		7.30	18.7	0.0	Low	Satisf.	L. Plast	Neg.
207-7-2A	Lockatong	NA	NA	3.95	53.42	15.27	5.76	1.47	4.10	3.68	4.57	4.07	3.34	0.87	NA	NA	<0.03	0.08	100.61	9.20	23.0	4.0	Fair	Poor Scum	Short	Pos.
207-7-2B	Lockatong	NA	NA	3.43	52.23	16.85	7.78	0.22	2.51	3.50	2.90	4.91	4.53	0.90	NA	NA	> 0.01	0.07	99.84	9.30	23.0	5.0	Good	Fair	Short	Pos.
207-8-4	Brunswick	5.06	0.55	2.64	52.86	18.28	7.95	0.86	2.82	2.86	2.62	4.11	3.36	0.83	NA	NA	None	0.19		7.40	20.0	0.0	Low	Satisf	L. Plast.	Neg.
208-2-3	Brunswick	5.22	0.22	2.86	62.06	15.74	2.77	3.16	2.82	1.73	1.94	1.65	2.26	0.78	NA	NA	None	0.11		7.30	19.6	0.0	Low	Satisf	L. Plast.	Neg.
208-3-4	Lockatong	6.73	0.47	3.98	50.00	18.22	4.81	3.16	3.63	3.43	3.06	3.67	4.13	0.72	NA	NA	None	0.29		7.40	20.0	0.0	Low	Satisf	L. Plast.	Neg.
208-5-2A	Lockatong	NA	NA	5.76	50.16	17.17	8.15	0.78	2.27	4.20	2.02	4.89	3.72	0.90	NA	NA	<0.01	0.07	100.10	9.15	22.0	5.0	Good	Good Scum	Short	Pos.
208-5-2B	Lockatong	8.38	0.77	4.58	50.36	16.22	3.84	3.02	5.64	3.93	2.83	3.24	2.14	0.62	NA	NA	None	0.95		9.10	22.0	5.5	Good	Good	Short	Pos.
208-5-2C	Lockatong	8.24	0.46	4.94	47.77	19.87	4.72	2.30	3.98	4.52	3.74	2.32	4.13	0.67	NA	NA	None	0.08		9.40	22.0	5.0	Good	Good	Short	Pos.
218-1-1A	Lockatong	6.21	0.60	3.44	49.68	18.95	4.15	3.74	3.50	3.29	2.87	4.40	3.88	0.83	0.21	0.12	0.03	0.06		8.20	22.2	0.0	Low	Satisf	L. Plast.	Neg.
218-1-1B	Lockatong	11.24	0.52	3.32	44.02	16.66	1.84	4.96	7.21	4.29	8.24	4.20	3.42	0.68	0.16	0.14	0.08	0.81		7.40	19.7	0.0	Low	Satisf	L. Plast.	Pos.
218-1-2	Lockatong	6.77	0.37	3.39	50.50	18.25	2.38	5.25	4.12	3.01	3.54	4.11	4.20	0.78	0.16	0.11	0.03	0.26		7.40	19.8	0.0	Low	Satisf	L. Plast.	Neg.
Northampton																										
195-9-4	Martinsburg Slate	7.80	0.19	3.86	57.20	15.28	2.55	4.10	4.84	2.61	3.75	1.08	2.40	0.70	NA	NA	0.61	0.38		8.50	20.8	2.5	Low	Satisf	L. Plast.	Pos.
195-9-5	Martinsburg Slate	7.17	0.27	4.33	57.66	16.23	2.56	4.18	4.64	2.82	2.99	1.08	2.40	0.85	NA	NA	0.79	0.17		8.40	19.1	2.5	Low	Satisf	L. Plast.	Pos.
205-6-7	Martinsburg Slate	7.54	0.10	4.50	56.48	14.42	2.70	3.96	4.31	2.93	3.32	1.62	4.47	0.82	NA	NA	0.65	0.42		8.30	20.9	0.0	Low	Satisf	L. Plast.	Pos.
205-8-5	Martinsburg Slate	6.15	0.10	3.30	60.02	14.61	1.04	4.82	2.97	3.24	2.60	1.57	4.54	0.85	NA	NA	0.57	0.26		8.40	20.8	0.0	Low	Satisf	L. Plast.	Pos.
205-9-6	Martinsburg Slate	5.85	0.38	3.82	61.00	14.07	1.76	4.75	1.97	3.37	0.77	1.46	4.42	0.67	NA	NA	0.76	0.58		7.30	18.9	0.0	Low	Satisf	L. Plast.	Pos.
206-1-1	Martinsburg Slate	6.66	0.14	4.86	59.22	15.60	1.98	4.18	2.62	3.33	0.68	1.46	4.42	0.68	NA	NA	0.72	0.70		9.90	15.7	0.0	Low	Satisf	L. Plast.	Neg.
206-1-2	Martinsburg	4.08	0.05	3.60	64.08	15.68	3.20	3.46	0.55	2.92	1.32	0.86	3.46	0.72	NA	NA	0.04	0.35		9.70	18.5	0.0	Low	Satisf	L. Plast.	Neg.
215-2-3	Martinsburg	5.37	0.61	3.74	60.94	15.64	6.00	1.30	1.16	2.68	0.96	0.99	3.46	0.72	NA	NA	1.28	0.71		9.50	13.6	0.0	Low	Satisf	L. Plast.	Neg.
215-7-4	Martinsburg	4.86	0.34	4.41	60.02	18.39	1.02	3.89	1.51	3.09	0.66	0.99	3.46	0.77	NA	NA	0.42	0.63		7.40	13.5	0.0	Low	Satisf	L. Plast.	Neg.
Schuylkill																										
166-6-3	Mahantango	4.12	0.49	NA	75.00	10.50	4.04	0.89	0.82	1.02	0.29	0.57	2.10	0.93	NA	NA	<0.02	0.18		7.80	23.0	3.0	Good	Good	Short working	Neg.
176-5-4	Mahantango	4.38	0.12	NA	69.00	13.00	3.50	3.47	0.68	1.06	0.55	0.81	3.10	0.97	NA	NA	0.03	0.31		8.50	20.0	0.5	Good	Short working	Short working	Pos.
176-6-5	Mahantango	4.37	0.25	NA	69.00	13.00	5.11	1.99	0.37	0.97	0.59	0.90	3.20	0.97	NA	NA	>0.07	0.22		7.40	19.0	1.0	Good	Good	Short working	Pos.
176-7-6	Mahantango	3.65	0.09	NA	73.20	11.00	3.80	1.95	0.38	0.88	0.37	1.65	2.40	1.00	NA	NA	0.16	0.22		8.20	22.0	0.0	Good	Fair	Fairly Plastic	Pos.
York																										
148-9-3	New Oxford	4.68	1.35	4.60	58.94	18.09	7.81	0.50	1.41	2.57	0.06	1.65	2.02	0.90	NA	NA	0.07	0.07		5.50	16.7	0.0	Low	Satisf	L. Plast.	Neg.
148-9-4	New Oxford	6.99	1.75	4.10	50.14	18.53	8.26	1.15	4.33	3.22	2.43	1.81	2.26	0.91	NA	NA	None	0.43		7.10	14.8	0.0	Low	Satisf	Non-Plast.	Neg.
149-2-2	New Oxford	5.38	1.31		63.50	14.50	8.43	0.05	0.73	1.44	0.44	1.26	3.70	0.98	NA	NA	>0.02	0.14		5.82	19.8	0.0	Good	Fair	Short working	Neg.
149-2-3	Kinzers	4.62	0.93	4.59	59.16	17.94	4.83	1.69	0.10	3.29	0.00	0.39	6.01	0.97	0.16	0.01	0.00	0.11		5.80	17.1	0.0	Low	Satisf	L. Plast.	Neg.